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CONTRIBUTING FACTORS TO ACCIDENTS BY OLDER DRIVERS: R&D PLAN AND EMPIRICAL STUDIES

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by

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16 Abstract

The purpose of this project was to develop the technical and experimental means to test the performance of older drivers (R&D Plan), and to conduct three empirical studies to determine performance differences at intersections (Empirical Studies).

Literature that describes the probable causes of older driver intersection accident involvement was reviewed. Two focus groups were conducted that elicited the difficulties and compensation strategies that older drivers have with intersection travel. Discussions confirmed that left turn and merging decisions are problematic, and that specific adaptations to intersection demands are the exception.

In a second study, older and younger driver performance at intersections was examined using a modified flicker method (MFM). This paradigm required participants to determine whether pairs of alternating images contained critical objects (e.g., car, pedestrian) while making a decision whether to proceed with an intersection manoeuvre. Using logistic regression, both age and time were significant predictors of decision accuracy.

A third study, conducted in the University of Calgary Driving Simulator, partially replicated and extended the results of the MFM study. In simulated intersection scenarios, the performance of older and younger drivers at intersections differed in their perception response times to vehicles placed on a collision vector, and in their responses to a last-second light change.

The conclusions synthesize the results of the three studies, and recommendations are made for future research.

17 Key Words

Older drivers, intersection accident, selective attention, intersection countermeasures, focus group, modified flicker method, change blindness, driving simulation

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16 Résumé

Ce projet a consisté à mettre au point des techniques et des devis expérimentaux pour mesurer la performance des conducteurs âgés (plan de R&D), et à mener trois études empiriques pour déterminer les écarts de performance entre divers groupes d'âge aux intersections (études empiriques).

Les chercheurs ont d'abord passé en revue les rapports de recherche faisant état des causes probables des accidents mettant en cause des conducteurs âgés aux intersections. Ils ont ensuite organisé deux groupes de discussion pour mieux comprendre les difficultés que posent les intersections aux conducteurs âgés ainsi que les stratégies qu'ils utilisent pour surmonter ces difficultés. Ces séances ont confirmé que les virages à gauche et l'insertion dans une file de voitures sont des situations difficiles, et que les stratégies spécialement adaptées pour parer à ces difficultés sont plutôt rares.

Une deuxième étude a consisté à étudier la performance de conducteurs jeunes et âgés aux intersections, à l'aide d'une méthode de stimulation intermittente modifiée (SIM). Les participants devaient déterminer si des paires d'images présentées en alternance contenaient des objets critiques (p. ex., une voiture, un piéton), en même temps qu'ils devaient décider d'effectuer ou non une manœuvre à une intersection. Une analyse de régression logistique des résultats a révélé que l'âge et le temps alloué pour prendre la décision sont des facteurs décisifs de la justesse de celle-ci.

Une troisième étude a été menée dans le simulateur de conduite de l'Université de Calgary. Cette étude avait pour but de reproduire en partie l'étude SIM et d'en approfondir les résultats. En présence de scénarios d'intersections, les conducteurs jeunes et les conducteurs âgés ont affiché des performances différentes en ce qui a trait au délai de perception de véhicules placés sur une trajectoire de collision, et au temps de réaction à un changement de feu in extremis.

Le rapport résume les conclusions des trois études et formule des recommandations quant à d'autres travaux de recherche à entreprendre.

17 Mots clés

Conducteurs âgés, accident à une intersection, attention sélective, contre-mesures préventives aux intersections, groupe de discussion, méthode de stimulation intermittente modifiée, cécité au changement, simulation de conduite

18 Diffusion

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EXECUTIVE SUMMARY

The objectives of this project were to create the technical and experimental means to test older drivers at intersections (R&D Plan) and to empirically determine the contribution of a number of performance factors to older driver intersection accidents (Empirical Studies). The analysis and testing of older and younger driver performance at intersections is expected to make a significant contribution to the knowledge about intersection accidents. Through greater knowledge, recommendations can be put forward to investigate driver and passenger fatalities and injuries.

The first part of this project (R&D Plan) developed new methods to assess the contribution of motion perception, and selective and divided attention to vehicle accidents in realistic situations without putting drivers in harm's way. The specific objectives of the R&D Plan were to:

- Produce a state-of-the-art report on the etiologies, and behavioural and performance precursors to older driver intersection accidents, based on a review of appropriate literature.

- Develop digital scenarios of representative intersections that vary in traffic flow, sign and signal complexity, and space and time constraints available for a turn decision; and develop presentations so that individuals can turn right, turn left or proceed through an intersection, depending on the experimental protocol.

- Develop, debug, calibrate, and pilot the means to integrate eye tracking with digital video.

- Develop an experimental design for the empirical testing of older drivers at intersections.

The second part of this project was to undertake empirical studies involving four primary research activities:

1) Conduct a series of focus groups with older drivers to elicit discussion of general and specific intersection difficulties and compensation strategies.

2) Run an extensive study of older and younger drivers using a modified change blindness paradigm. Participants will complete background screening tests for acuity and contrast sensitivity, and a driver intersection behaviour questionnaire.

3) Conduct a driving simulation experiment that examines turn decisions by older and younger drivers at intersections that vary in complexity.

4) Discuss the implications of the change blindness and driving simulation studies for intelligent transportation system (ITS) intersection countermeasures.

Literature Review

Some older drivers have difficulty making turns at intersections. Typically, older drivers travel fewer kilometres per year, yet their accident risk for turning manoeuvres is greater than many other age groups. Based on the Fatality Analysis Reporting System (FARS) in the U.S., the relative risk for accident involvement, where the older driver has failed to yield the right of way, increases with driver age for a variety of intersection types (Preusser et al., 1998). Clearly, older drivers—especially those 75 years and older—have difficulties coping with the complexity of dynamic traffic intersections and traffic control information. Missed stop signs and traffic lights were identified as frequent contributors.

Failures of perception, attention, memory, and action are frequently used to explain why signs, signals, and other vehicles are missed by older drivers. Age-related declines in divided and selective attention, as measured by the Useful Field of View (UFOV) test, have been found to be related to intersection accidents (Ball et al., 1993). A number of studies are reviewed that found significant relationships between lower divided attention scores and accident involvement

(Owsley, in press). Performing two driving activities simultaneously, such as identifying a peripheral sign and a central vehicle, declines with age (McDowd & Shaw, 2000).

A method within visual perception called the flicker paradigm has been used to understand the capability of observers to detect changes with a pair images that alternate with a mask in between (Rensink, et al., 1997). Even after looking directly at the images for some time, it is difficult to determine whether an object is changing from one image to the next. This phenomenon of not being able to see objects appearing and disappearing has been called change blindness. An effortful search of the images is engaged but, for reasons of attention or memory, the person does not necessarily see the object changing. Studies that used the flicker paradigm were reviewed. Among other effects, changes to objects that were more central within the images were more likely to be detected than objects embedded in the background of an image. The change blindness phenomenon is similar to why older drivers may miss signs, signals, and other vehicles.

Despite age-related declines in capabilities, older drivers make compensations in how they drive so that risk is further reduced (Lundberg et al., 1998). However, if older drivers are not aware of age-related declines such as loss of visual acuity, they may not make compensations in their driving (Holland & Rabbitt, 1992). It is not known whether all compensations that older drivers engage in result in reduced risk. For example, older drivers who drive slowly may not be able to enter fast-moving traffic and may confuse other drivers as to their intent.

Focus Group Study

To determine the extent of general intersection difficulties and compensation strategies used by older drivers at intersections, several focus groups were conducted. A focus group is a guided discussion that allows information to be gathered from a specific population sample. Usually a session consists of 10 to 12 volunteers and a moderator to guide the discussion. Five sessions were conducted at a senior's facility in Calgary, Alberta, called the Kerby Centre. Volunteers (aged 65+) were recruited from the same facility. The general topic of discussion included driving behaviours within the Calgary traffic environment. Further concerns included navigating intersections, merging, uncontrolled intersections, left turns, and yielding while waiting to enter busy thoroughfares. The focus groups enabled comments to be gathered from the informal interaction, and the majority of volunteers completed a driver experience questionnaire.

A number of problem intersections were identified and common strategies that older drivers used to overcome particular difficulties were revealed. It was not surprising that left turns and merging were two major areas of concern. According to these drivers, merge lanes were either too short or poorly designed to merge successfully. Some older drivers may require more time and distance in a merge situation to make a comfortable manoeuvres. Problems associated with left turns were due to busy roads, the absence of advance turn signs, and comprehensible signage. Some drivers seem to feel uncomfortable with merges and unprotected left turns and they opt to avoid these locations. Surprisingly, only three of the volunteers reported reduced driving at night and another three strategically restricted their driving to non-rush hour times. The focus groups outlined important areas for further research. This is in line with previous literature. Overall, the focus group results confirmed previous literature findings of known problems with older driver intersection navigation (Staplin et al., 1997).

Modified Change Blindness Study

The modified change blindness study examined the effect of time constraints on younger (18-25), middle-aged (26-64), young-old (65-73), and old-old (74+) drivers on intersection decisions. It was expected that increased time pressure in intersection situations would adversely affect a driver's ability to process information, select a course of action, and act upon this decision. A modified flicker paradigm was used to address these questions (Rensink, et al., 1997). Typically, an image (A) is alternated with a modified image (A') each for a short duration (250 ms) with a blank field or mask (80 ms) between A and A'. In the present study, a focus screen (or prime) that indicated the expected direction of travel (i.e., left, right, or straight) was added prior to the alternation of images. Forty-two daytime images were selected from 2500 intersection approaches in Calgary, Winnipeg, and Montreal that were photographed using a digital camera. A variety of elements including pedestrians, vehicles, signs, and signals were manipulated. The goal of each of the 62 participants was to decide whether the indicated direction of travel in the pair of intersection images was safe (press accelerator) or not (press brake).

The primary independent variable was the overall length of time for the image alternations (5 s and 8 s). Using logistic regression, analysis of the go/no-go decisions found age and time were significant predictors of intersection decision accuracy in 14 of the 36 intersections tested. Decision accuracy was significantly greater in the 26-64 age group than in the older age groups (65-73, 74+). The largest deviation was found between the youngest age group (18-25) and the oldest two age groups. Subtle variations of the size of the object that changed, luminance change, and the relevancy of the change to a turn decision affected decision accuracy for certain intersections. Qualitative analyses of responses illustrated how specific and varied information affects intersection decisions. In particular, older drivers tended to fixate on traffic control devices and signs to formulate their decisions to the exclusion of other sources of information such as pedestrians and other vehicles. Overall, the results of the study suggest that certain types of intersection information and the available time to form a decision are critical to older driver decision accuracy.

As a drivers test, the modified flicker method (MFM) with the 14 predictive intersections in it has the potential to be developed into a test to identify drivers with scanning difficulties. With a range of intersection images, the MFM could be used to train drivers to detect expected and unexpected hazards at intersections. The complexity of intersections tends to evolve with the addition of new signs and signals, and as traffic flow increases and structural modifications are made. The MFM could be also adapted to determine the ease with which drivers are able to process the overall attention load of intersection modifications to make safe turn decisions.

Driving Simulation Study

The purpose of the driving simulation study was to replicate and extend the findings of the modified flicker method (MFM) study in the dynamic but safe driving conditions provided by the simulator. The University of Calgary Driving Simulator (UCDS) at the time of this study was the most advanced driving simulator in Canada. The UCDS presents an interactive traffic environment in which to drive and includes the behaviour of other vehicles, changes to traffic signals, and pedestrian behaviours (see Figure 1).

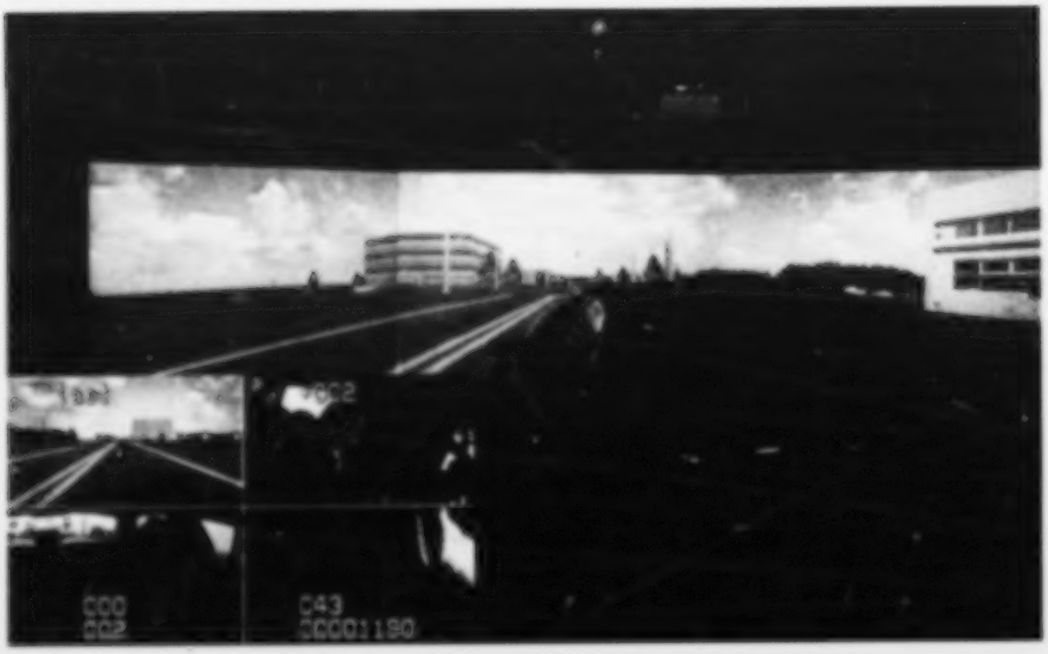

Figure 1. The University of Calgary Driving Simulator (UCDS) is shown with projectors, screens, Saturn SL-1, and internal camera views of the driver.

Sixteen drivers volunteered for the study; half older (65 to 80) and half younger (18 to 25). Each drove training and experimental sessions in the driving simulator. Drivers responded to four critical events among a series of intersections encountered. Younger drivers responded significantly faster to a light change from green to yellow, the sudden appearance of a vehicle from the left, and the appearance of a pedestrian when dynamic flicker was added to the traffic scene presented. Response types (e.g., braking or accelerating) also differed between the two age groups. The study extends previous research on driver performance at intersections when critical events occur. The use of a dynamic flicker followed by the sudden appearance of hazards in the intersection is an extension of the MFM to driving simulation.

Conclusions and Recommendations

1) The scope and depth of the three studies in combination provide a multi-method approach to acquire a greater understanding of the general and specific driver performance issues at intersections. The focus groups, modified flicker method study, and the driving simulation study confirm quantitatively and qualitatively that older drivers are concerned about

intersections, fail to detect information and hazards with increased age, and do not respond as quickly as younger drivers when critical events occur.

2) To determine the extent of general intersection difficulties and compensation strategies used by older drivers, several focus groups were conducted. The objective of these focus groups was to understand the difficulties that older drivers face each day to be mobile. A variety of adaptations to overcome these hindrances were discussed, such as not driving at night and avoiding problematic manoeuvres. As a general method, the focus groups provided extensive detail about older driver mobility and safety concerns.

3) The modified flicker method (MFM) was developed to understand driver selective attention at intersections. The MFM provides a driver a turn goal (i.e., right, left or straight) and a limited time to determine whether the turn is safe. The 14 intersections, where age and/or time are predictive of turn decision accuracy, could be used as a diagnostic test for older drivers. In contrast, the flicker method, when used to understand visual attention and cognition, does not provide the observer with a relevant goal or limit the time to view alternating images. Instead the focus is whether a change is detected.

4) The goal of the MFM was to create a means by which older drivers could be diagnostically assessed for attentional search. Similarly, worst-case design for intersections could be tested to determine whether drivers' visual attention can adequately scan for salient information to make safe turn decisions. Training drivers to scan for expected and unexpected information and hazards is a logical extension of this research. Future research is required to determine the viability of these three applications.

5) The driving simulation study confirmed and extended previous older driver performance research at intersections. The driving simulation study was the first complete experiment in the University of Calgary Driving Simulator (UCDS). The technical development, system integration, and validation of UCDS took six months to complete. With the integration of the eye movement system, significant contributions to transportation human factors, traffic safety, and in-vehicle intelligent transportation systems (ITS) are expected.

6) The relative risk of being in an intersection accident increases dramatically after the age of 75. Why this occurs from a driver performance level of analysis requires additional research. Perhaps foremost among possible follow-up questions is how attentional limitations interact with compensation strategies. Do older drivers tend to look for signs and signals, and thus are less likely to see other important, but unexpected, cars and pedestrians? Does the strategy lead to potential intersection conflicts? If many older driver intersection accidents are the result of failing to see traffic lights and signs, does this indicate a failure to adopt a strategy or that other events in the intersection momentarily cause the search strategy to be suspended or forgotten?

7) Can what is known about older drivers' attention limitations at intersections facilitate the development of intelligent transportation systems (ITS) countermeasures? A number of possible technologies are being developed to help drivers avoid collisions. These include vision enhancement systems (VES), collision warning systems (e.g., auditory, haptic, visual), and navigation systems. Each system has potential advantages and disadvantages (see Caird, in press). Based on this research, the important design principles of any intersection ITS application should include: complementing existing (and potentially error-prone) scan strategies; adding time to make adequate decisions; simplifying and prioritizing expected intersection information; and increasing the capability to detect unexpected events within a limited window of time. Research on the design details and necessary trade-offs is needed.

SOMMAIRE

Ce projet a consisté à mettre au point des techniques et des devis expérimentaux pour mesurer la performance des conducteurs âgés aux intersections (plan de R&D) et pour déterminer empiriquement la contribution d'un certain nombre de facteurs liés à la performance aux accidents mettant en cause des conducteurs âgés aux intersections (études empiriques). Une telle étude théorique et empirique de la performance des conducteurs jeunes et âgés aux intersections devrait faire grandement progresser les connaissances sur les accidents aux intersections. Et ces connaissances pourront à leur tour mener à la recommandation de travaux de recherche sur les accidents faisant des tués et des blessés chez les conducteurs et les passagers.

Au cours de la première phase du projet (plan de R&D), de nouvelles méthodes ont été mises au point pour étudier dans quelle mesure des facteurs comme la perception du mouvement, l'attention sélective et l'attention divisée contribuent aux accidents routiers. Ces méthodes placent les conducteurs dans des situations réalistes, mais sans jamais qu'ils soient en danger. Les objectifs particuliers du plan de R&D étaient les suivants :

- à partir d'une recherche documentaire, produire un rapport donnant l'état des connaissances sur l'étiologie des accidents des conducteurs âgés aux intersections et sur les facteurs liés au comportement et à la performance contribuant à ces accidents;

- élaborer, à l'aide d'images numériques, des scénarios représentant diverses intersections, en faisant varier les paramètres suivants : débit de circulation, complexité des panneaux indicateurs et des feux de signalisation, contraintes temporelles et spatiales pour décider d'effectuer ou non un virage; et mettre au point des présentations pour que les conducteurs puissent tourner à droite ou à gauche ou continuer tout droit à l'intersection, selon le protocole expérimental;

- développer, déboguer et étalonner un moyen d'intégrer le suivi oculaire à l'imagerie numérique, et en faire une étude pilote;

- mettre au point le plan d'expérience pour l'étude empirique des conducteurs âgés aux intersections.

La deuxième partie du projet consistait en des études empiriques. Celles-ci ont pris quatre formes :

1) groupes de discussion avec des conducteurs âgés, devant mener à une meilleure compréhension des difficultés générales et particulières posées par les intersections, et des stratégies utilisées pour surmonter ces difficultés;

2) étude approfondie de conducteurs jeunes et âgés, à l'aide d'un paradigme expérimental de cécité au changement modifié; les participants sont d'abord soumis à des tests d'acuité visuelle et de sensibilité aux contrastes, après quoi ils doivent remplir un questionnaire sur leur comportement de conducteur aux intersections;

3) expérience de simulation de conduite portant sur les décisions prises par les conducteurs jeunes et âgés d'effectuer ou non un virage à des intersections de complexité variable;

4) examen des conclusions à tirer des études sur la cécité au changement et des simulations de conduite en ce qui a trait au recours aux systèmes de transports intelligents (STI) pour améliorer la sécurité aux intersections.

Recherche documentaire

Certains conducteurs âgés ont de la difficulté à effectuer un virage à une intersection. Ainsi, même s'ils parcourent un nombre moins élevé de kilomètres par année au volant de leur voiture, ils courent un risque plus grand d'avoir un accident lors d'un virage que les conducteurs de n'importe quel autre groupe d'âge. Selon le FARS (*Fatality Analysis Reporting System*) des États-Unis, toutes proportions gardées, le risque d'accident asssocié au défaut du conducteur âgé de céder le passage augmente avec l'âge du conducteur, à plusieurs types d'intersections (Preusser et coll., 1998). Bref, les conducteurs âgés – en particulier ceux âgés de 75 ans et plus –

se trouvent démunis devant la complexité des intersections achalandées et d'une signalisation à l'avenant. Il n'est pas rare qu'ils brûlent un arrêt ou un feu rouge.

On invoque souvent des défaillances sur les plans de la perception, de l'attention, de la mémoire et de l'action pour expliquer pourquoi les conducteurs âgés ne voient pas les panneaux indicateurs, les feux de signalisation et les autres véhicules. Un lien a été établi entre la baisse d'attention sélective et la baisse d'attention divisée liées à l'âge, mesurées par l'outil UFOV (*Useful Field of View*), et les accidents aux intersections (Ball et coll., 1993). Des études ont également mis en évidence une corrélation significative entre de faibles scores au test d'attention divisée et le fait d'avoir un accident (Owsley, sous presse). L'exercice simultané de deux activités de conduite, comme voir un panneau indicateur et un véhicule situés respectivement en périphérie et au centre de son champ de vision, devient de plus en plus difficile avec l'âge (McDowd & Shaw, 2000).

Un paradigme expérimental de stimulation intermittente qui sert normalement à étudier la perception visuelle a été utilisé pour déterminer la capacité d'observateurs de détecter des changements dans une paire d'images présentées en alternance, avec un masque (zone en blanc) entre les deux (Rensink et coll., 1997). Or, même après avoir regardé directement les images pendant un certain temps, il est difficile de dire si un objet a changé d'une image à l'autre. Cette incapacité de percevoir l'apparition et la disparition d'objets est appelée «cécité au changement». La personne s'applique à scruter les images mais, pour des raisons ayant trait à l'attention ou à la mémoire, elle ne remarque pas toujours les changements. Les études qui avaient mis en œuvre ce paradigme expérimental ont été passées en revue. Elles ont entre autres révélé que les changements sont plus facilement détectés lorsqu'ils touchent des objets situés au centre de l'image plutôt qu'à l'arrière-plan. Le phénomène de cécité au changement ressemble à ce qui ce passe lorsque les conducteurs âgés brûlent un arrêt ou un feu rouge, et ne voient pas les autres véhicules.

Pour compenser la diminution de leurs capacités liée à l'âge, les conducteurs âgés adoptent des stratégies de conduite pour réduire le risque auquel ils sont exposés (Caird et coll., 1998). Mais il faut pour cela qu'ils soient conscients de la diminution de leurs capacités, comme de la baisse de leur acuité visuelle (Holland & Rabbitt, 1992). Et il n'est pas sûr que toutes les stratégies compensatoires utilisées par les conducteurs âgés diminuent effectivement le risque. Par exemple, ceux qui conduisent lentement ont généralement de la difficulté à s'insérer dans une file de véhicules qui roulent à bon train, et rendent les autres conducteurs perplexes quant à leurs intentions.

Groupes de discussion

Pour mieux connaitre l'ampleur des difficultés que représentent les intersections pour les conducteurs âgés, ainsi que les stratégies compensatoires qu'ils utilisent pour surmonter ces difficultés, les chercheurs ont organisé des groupes de discussion. Il s'agit de réunions de personnes qui participent à une discussion dirigée par un animateur, qui cherche à recueillir l'opinion d'un échantillon de population. Habituellement, une séance de discussion réunit de 10 à 12 participants autour d'un animateur. Deux séances ont été menées dans un centre pour personnes âgées de Calgary, Alberta, appelé le Kerby Centre; les participants (âgés de 65 ans et plus) avaient été recrutés sur place. La discussion avait pour thème général les comportements de conduite sur le réseau routier de Calgary. D'autres sujets ont aussi été abordés : les manœuvres aux intersections, l'insertion dans une file de véhicules, les intersections sans signalisation, les virages à gauche et l'attente d'un créneau pour s'engager sur une voie de circulation achalandée. Ces discussions ont permis de recueillir des commentaires formulés dans un cadre informel; de plus, la majorité des participants ont rempli un questionnaire sur leur expérience de conducteur.

Les participants ont pointé du doigt certaines intersections problèmes et ils ont fait état des stratégies qu'ils utilisent pour surmonter certaines difficultés. Comme on pouvait s'y attendre, les virages à gauche et les flots convergents représentent les deux grandes difficultés. Selon ces conducteurs, les voies de convergence sont trop courtes ou mal conçues. Certains conducteurs âgés ont parfois besoin de plus de temps et de distance pour bien faire une manœuvre d'insertion. Quant aux virages à gauche, leur difficulté vient de l'encombrement des routes, de l'absence de feux avancés et d'une signalisation confuse. Certains conducteurs sont tellement inconfortables dans des situations de flots convergents ou de virages à gauche sans protection qu'ils préfèrent modifier leur itinéraire pour s'y soustraire. Étonnamment, seulement trois participants ont déclaré s'abstenir, autant que possible, de conduire le soir, et trois autres se contentaient de conduire en dehors des heures de pointe. Les groupes de discussion ont mis en lumière quelques grands thèmes à aborder dans des travaux de recherche futurs. Dans l'ensemble, les commentaires exprimés ont confirmé les résultats de la recherche documentaire concernant les problèmes posés par les intersections aux conducteurs âgés (Staplin et coll., 1997).

Étude sur la cécité au changement

L'étude sur la cécité au changement a mis en lumière l'effet des contraintes temporelles sur les décisions des conducteurs jeunes (18-25 ans), d'âge moyen (26-64 ans), âgés «jeunes» (65-73 ans) et âgés «âgés» (74 ans et plus) aux intersections. On s'attendait que les contraintes temporelles particulièrement aiguës aux intersections diminuent la capacité des conducteurs de traiter l'information, de choisir un plan d'action et de mettre en pratique leur décision. Un paradigme expérimental de stimulation intermittente modifié a été utilisé pour élucider ces questions (Rensink et coll., 1997). Voici en quoi consiste l'essai : une image (A) est présentée au sujet en alternance avec la même image modifiée (A'), chacune pendant un court laps de temps (250 ms); une zone en blanc, ou masque, est intercalée pendant 80 ms entre les images A et A'. Dans la présente étude, un écran indiquant la direction que devait prendre le véhicule (gauche, droite ou tout droit) précédait la présentation des images. Quarante-deux photos prises de jour à l'aide d'un appareil photo numérique avaient été choisies dans une banque d'images de 2 500 intersections à Calgary, Winnipeg et Montréal. Les éléments modifiés étaient des piétons, des véhicules, des panneaux indicateurs et des feux de signalisation. Chacun des 62 participants devait décider s'il pouvait en toute sécurité prendre la direction indiquée (en appuyant sur l'accélérateur) ou non (en mettant les freins) dans l'une et l'autre des versions de l'intersection.

La variable indépendante principale était la durée globale pendant laquelle les images étaient présentées (5 s et 8 s). Une analyse de régression logistique des décisions d'effectuer le virage ou non a révélé que dans 14 des 36 intersections étudiées, l'âge et et le temps étaient les facteurs décisifs de la justesse des décisions. Celles-ci étaient significativement plus justes chez les 26-64 ans que dans les groupes plus âgés (65-73 ans, 74 ans et plus). Le principal écart séparait le groupe le plus jeune (18-25 ans) et les deux groupes les plus âgés. Dans le cas de certaines intersections, d'autres facteurs influaient sur la justesse des décisions : de légères variations des dimensions de l'objet, un changement de luminosité et la pertinence de la modification au regard de la décision d'effectuer un virage. Des analyses qualitatives des réponses ont montré comment une information précise et variée influe sur les décisions aux intersections. Ainsi, les conducteurs âgés avaient tendance à se concentrer sur les feux de signalisation et les panneaux indicateurs pour prendre leurs décisions, à l'exclusion d'autres éléments d'information, comme les piétons et les autres véhicules. Globalement, les résultats de l'étude donnent à penser que certains types d'information associés aux intersections et le temps alloué pour prendre une décision sont les facteurs déterminants de la justesse des décisions prises par les conducteurs âgés.

La méthode de stimulation intermittente modifiée (SIM) appliquée aux images des 14 intersections qui se sont avérées prédictives pourrait, moyennant certaines adaptations, servir de test pour dépister les conducteurs qui ont de la difficulté à balayer l'environnement. Appliquée à une gamme d'images d'intersections, la SIM pourrait servir à enseigner aux conducteurs à déceler les dangers attendus et inattendus aux intersections. La complexité d'une intersection a tendance à augmenter en raison directe du nombre de panneaux indicateurs et de feux de signalisation, de l'intensité de la circulation et des modifications touchant l'infrastructure. La SIM pourrait aussi servir à déterminer dans quelle mesure les conducteurs sont capables de traiter toute la charge attentionnelle associée aux modifications de l'intersection pour prendre en toute sécurité la décision d'effectuer un virage.

Étude de simulation de conduite

L'étude de simulation de conduite avait pour but de reproduire l'étude SIM et d'en approfondir les résultats dans les conditions dynamiques mais sûres offertes par un simulateur. Au moment de la présente étude, le simulateur de conduite de l'Université de Calgary (UCDS) était le plus avancé au Canada. La personne au volant est plongée dans un environnement routier interactif, et doit réagir au comportement d'autres véhicules, à des changements de feux et aux comportements de piétons (voir la figure 1).

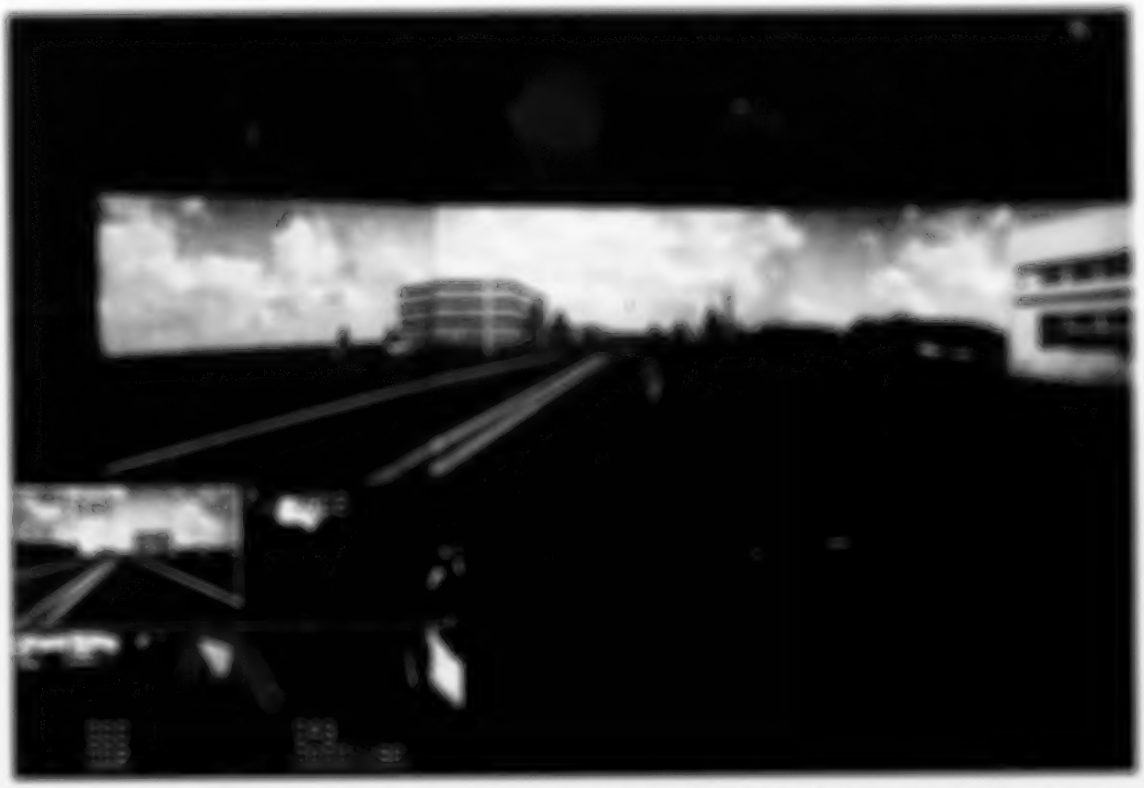

Figure 1. Le simulateur de conduite de l'Université de Calgary (UCDS) avec ses projecteurs, ses écrans, la Saturn SL-1 et des vues de la conductrice prises par une caméra embarquée.

Seize conducteurs se sont portés volontaires pour l'étude; la moitié étaient âgés (65 à 80 ans) et les autres étaient jeunes (18 à 25 ans). Ils ont tous reçu une formation avant de participer à l'expérience dans le simulateur. L'expérience comportait quatre scénarios de conduite le long d'une série d'intersections, au cours desquels survenaient quatre événements critiques. Les jeunes conducteurs réagissaient significativement plus rapidement à un changement de feu du vert au jaune, à l'apparition soudaine d'un véhicule sur la gauche et à l'apparition d'un piéton, lorsqu'un clignotement dynamique était ajouté à la scène présentée. De plus, les types de réactions (p. ex., freinage ou accélération) différaient également entre les deux groupes d'âge. L'étude a donc permis d'en savoir plus sur la performance des conducteurs aux intersections lorsque survient un événement critique. L'utilisation d'un clignotement dynamique suivi de l'apparition soudaine de dangers dans l'intersection est une adaptation de la SIM à la simulation de conduite.

1) Les trois études combinées, qui font appel à des méthodes multiples, ont une portée et une profondeur qui ouvre la voie à une meilleure compréhension des difficultés générales et particulières qui nuisent à la performance aux intersections. Les groupes de discussion, l'étude sur la cécité au changement et l'étude de simulation de conduite confirment tant quantitativement que qualitativement que les conducteurs âgés craignent les intersections, qu'ils ne réussissent pas toujours, avec l'âge, à décoder l'information et les dangers, et qu'il ne réagissent pas aussi rapidement que les jeunes conducteurs à des événements critiques subits.

2) Pour déterminer l'ampleur des difficultés générales que représentent les intersections ainsi que les stratégies compensatoires utilisées par les conducteurs âgés, plusieurs groupes de discussion ont été organisés. Le but de ces rencontres était de mieux comprendre les obstacles que les conducteurs âgés doivent affronter quotidiennement pour demeurer mobiles. Ceux-ci ont mentionné diverses stratégies auxquelles ils ont recours pour surmonter ces obstacles comme, par exemple, s'abstenir de conduire la nuit et éviter les situations où il faut effectuer des manoeuvres complexes. Bref, les groupes de discussion ont permis de recueillir une information détaillée sur les problèmes de mobilité et de sécurité auxquels font face les conducteurs âgés.

3) La méthode de stimulation intermittente modifiée (SIM) a permis d'étudier l'attention sélective des conducteurs aux intersections. La SIM indique au conducteur la direction qu'il doit prendre (droite, gauche ou tout droit) et limite le temps dont il dispose pour décider s'il peut effectuer un virage en toute sécurité. Les 10 intersections où l'âge et/ou le temps se sont avérés des facteurs déterminants de la justesse des décisions (d'effectuer ou non le virage) pourraient servir de test diagnostic pour les conducteurs âgés. À l'inverse, lorsque la méthode de stimulation intermittente est utilisée pour l'étude de l'attention visuelle et de la cognition, elle ne donne au sujet aucune consigne de virage et aucune limite de temps pour observer les images en alternance. Il lui est plutôt demandé de détecter un changement.

4) Le but de la SNV était de créer un moyen d'évaluer la capacité d'attention des conducteurs âgés. On pourrait aussi envisager de présenter aux conducteurs les intersections les plus mal conçues pour déterminer si leur degré d'attention visuelle est suffisant pour déceler toute l'information nécessaire pour décider à coup sûr de l'opportunité d'effectuer un virage. Enseigner aux conducteurs à balayer visuellement l'environnement à la recherche d'information et de dangers attendus et inattendus serait un prolongement naturel de cette recherche. D'autres recherches devront être entreprises pour établir la validité de ces trois applications.

5) L'étude de simulation de conduite a confirmé et enrichi les résultats des recherches antérieures sur la performance des conducteurs âgés aux intersections. Cette étude fut la première expérience complète menée dans le simulateur de conduite de l'Université de Calgary (UCDS). Le développement technique, l'intégration du système et la validation du UCDS a nécessité six mois de travail. L'intégration du système de suivi des mouvements oculaires devrait permettre des percées importantes dans les domaines des facteurs humains en transport, de la sécurité routière et des systèmes de transport intelligents (STI) embarqués.

6) Toutes proportions gardées, le risque d'avoir un accident à une intersection augmente énormément après l'âge de 75 ans. Il y a forcément des liens à établir entre cette tendance et la performance du conducteur, mais pour cela, d'autres recherches s'imposent. Une des questions les plus importantes à étudier, peut-être, est l'interaction entre les limites de l'attention et les stratégies compensatoires. Se peut-il que les conducteurs âgés aient tendance à rechercher les panneaux indicateurs et les feux de signalisation, et soient ainsi moins attentifs à d'autres données importantes, mais inattendues, comme la présence de voitures et de piétons? Leurs stratégies peuvent-elles mener à des situations conflictuelles aux intersections? Comme de nombreux accidents mettant en cause des conducteurs âgés aux intersections sont causés par le fait que le conducteur n'a pas vu les feux et les panneaux de signalisation, doit-on comprendre que celui-ci a manqué à sa stratégie ou que d'autres événements l'ont amené à suspendre ou oublier momentanément sa stratégie de recherche?

7) Les connaissances acquises au sujet des limites d'attention des conducteurs âgés aux intersections peuvent-elles faciliter l'élaboration de contre-mesures faisant appel à des STI *embarqués*? Diverses technologies actuellement en développement visent à aider les conducteurs à éviter les collisions. Mentionnons à cet égard les systèmes d'aide à la vision (VES), les systèmes anti-collision (p. ex., signaux sonores, haptiques, visuels) et les systèmes de navigation. Chaque système comporte des avantages et des inconvénients potentiels (voir Caird, sous presse). Selon cette recherche, la conception d'une application STI destinée à une intersection devrait incorporer les principes suivants : compléter les stratégies de recherche existantes (potentiellement défaillantes); allonger le temps disponible pour prendre les décisions; simplifier les éléments d'information attendus aux intersections en faisant clairement ressortir les plus importants; et accroître la capacité de détecter des événements inattendus dans un laps de temps limité. Des travaux de recherche s'imposent sur les détails de conception et les compromis nécessaires.

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1. INTRODUCTION

Intersection negotiation can be difficult for older drivers. In general, they travel fewer kilometres, yet have higher accident risk than most other age groups (Evans, 1988; Massie, et al., 1995; McGwin & Brown, 1999; Stamatiadis & Deacon, 1998). In particular, older drivers are over-represented in most types of intersection accidents (Preusser et al., 1998). Why older drivers are over-represented is only partially understood. Typically, it is assumed that failures of perception or attention contribute to intersection accidents and, in general, measures of divided and selective attention are modestly predictive of older driver accidents (Owsley, in press).

1.1 Project Overview

The objectives of this project were to create the technical and experimental means to test older drivers at intersections (R&D Plan) and to empirically determine the contribution of a number of performance factors to older driver intersection accidents (Empirical Studies). The analysis and testing of older and younger driver performance at intersections is expected to make a significant contribution to the knowledge about intersection accidents. Through greater knowledge, recommendations can be put forward to investigate driver and passenger fatalities and injuries.

Understanding the degree to which various older driver capabilities contribute to intersection accidents logically precedes the development of effective countermeasures (Caird, in press). The relative contribution of vision, perception, attention, decision making, and action to intersection errors by older drivers is the focus of the empirical studies that were undertaken. The studies examined to what extent younger and older drivers were able to successfully navigate a variety of traffic intersections. Three separate research phases were used to achieve this objective. First, a series of focus groups elicited general and specific concerns that older drivers have with intersection travel. For example, a list of the ten most difficult intersections to drive in Calgary was identified. Second, a modified flicker method (MFM) was used to determine the contribution of selective attention to intersection decision making. Finally, a driving simulator was used to test the performance of older and younger drivers at intersections when confronted with a range of threats. Results of the studies will be used to identify the most effective intelligent transportation systems (ITS) countermeasures for older driver intersection accidents.

In the first phase, two focus groups were held at the Kerby Centre, a senior's facility in Calgary. A common set of questions was used by a facilitator to guide the discussion of 17 participants with varied driving backgrounds. Perceptions of intersections that were more problematic were discussed. Specific incidents, in the past several months, that volunteers had either success or difficulty executing were described. Left turns and merging manoeuvres were a common theme. A variety of compensation strategies and means to maintain driving skill were also discussed (see Section 3 for details).

The second phase of the research adapted the change blindness paradigm to test attentional performance at intersections. The change blindness paradigm has been used by visual attention researchers to understand how attention is used to maintain the awareness of objects, such as vehicles and signs, over time. The change blindness paradigm required participants to determine whether a critical object changes (e.g., a car or a pedestrian) in a pair of alternating images while making a decision to proceed with an intersection manoeuvre or not. The study required participants to attend to the most important information in a traffic intersection as they decided whether certain directions of travel (i.e., right, left, or straight) could be accomplished safely. Intersections from Calgary, Winnipeg, and Montreal were selected from approximately 2500 photographed intersection approaches. The selection of each was based on a number of criteria, including the number of vehicles, pedestrian presence, signs, signals, geometric design, and the potential for manipulation. Younger (18 to 25), middle-aged (26 to 64), young-old (65 to 73), and old-old (74+) drivers were presented with a range of intersections that varied in complexity. Response accuracy, decision confidence, and relevance of intersection information was measured.

In the third phase, the University of Calgary Driving Simulator (UCDS) was used to test older driver performance at a number of intersections that varied in difficulty. Driving simulation offers a safe environment to assess the consequences of a range of driving responses without consequences to the participant. A training route was driven to familiarize participants with the acceleration, deceleration, and handling characteristics of the simulator. During the experimental session, drivers encountered a series of intersections in succession. A few intersections contained events that required drivers to respond as quickly as possible to avoid collision with a pedestrian, collision with another vehicle, and running a red light. Perception response time, lateral deviation, and collisions were measured.

These studies, taken together, are expected to extend current knowledge about the relationship between older driver performance and accident contributors. Specifically, aspects of intersection turns that cause the greatest difficulties for older drivers are sought as well as contextual factors that interact with diminished visual, perceptual, and attentive capabilities to increase risk.

1.2 Project Objectives

The first part of this project (R&D Plan) developed new methods to assess the contribution of motion perception, and selective and divided attention to vehicle accidents in realistic situations without putting drivers in harm's way. The specific objectives of the R&D Plan were to:

- Produce a state-of-the-art report on the etiologies, and behavioural and performance precursors to older driver intersection accidents, based on a review of appropriate literature.

- Develop digital scenarios of representative intersections that vary in traffic flow, sign and signal complexity, and space and time constraints available for a turn decision; and develop presentations so that individuals can turn right, turn left or proceed through an intersection depending on the experimental protocol.

- Develop, debug, calibrate, and pilot the means to integrate eye tracking with digital video.

- Develop an experimental design for the empirical testing of older drivers at intersections.

The second part of this project was to undertake empirical studies involving four primary research activities:

1) Conduct a series of focus groups with older drivers to elicit discussion of general and specific intersection difficulties and compensation strategies.

2) Run an extensive study of older and younger drivers using a modified change blindness paradigm. Participants will complete background screening tests for acuity and contrast sensitivity, and a driver intersection behaviour questionnaire.

3) Conduct a driving simulation experiment that examines turn decisions by older and younger drivers at intersections that vary in complexity.

4) Discuss the implications of the change blindness and driving simulation studies for intelligent transportation systems (ITS) intersection countermeasures.

Each subsequent section of the report presents the outcome of each of these objectives. Section 2 reviews the literature concerning older driver accident contributors, useful field of view (UFOV), change or inattentional blindness, and driver adaptation strategies. Section 3 presents the results of the focus group discussions. Sections 4 and 5 describe the methods and results of the change blindness and driving simulator studies, respectively. The final section synthesizes the results of the three studies and discusses the implications of the findings for ITS countermeasures and future research.

2. LITERATURE REVIEW

Four specific areas of research were reviewed:

1) Studies that describe older driver intersection accidents and associated precursors;
2) Human performance predictors of older driver accidents, in particular, useful field of view (UFOV) attentional tests;
3) Studies in visual attention that have used the change blindness paradigm;
4) Older driver compensation strategies.

Studies from these four research domains are described in-depth and synthesized in subsequent sections.

2.1 Older Driver Intersection Accidents

Turning manoeuvres can be especially difficult for older drivers (usually defined as individuals aged 65 and above).[1] They typically travel fewer kilometres per year, yet their accident risk for turning manoeuvres is greater than many other age groups. Specifically, older drivers are over-represented on the basis of miles driven in intersection accidents (Hakamies-Blomqvist, 1993; Hauer, 1988; Kim et al., 1997; McGwin & Brown, 1999; McKelvey et al., 1988; Stamatiadis et al., 1990; 1991a; 1991b), left turn accidents (Garber & Srinivasan, 1991; McGwin & Brown, 1999; Staplin & Lyles, 1991), and gap acceptance accidents (Faulkner, 1975; Moore et al., 1982; Rassan & Sabey, 1972; Staplin & Lyles, 1991). For example, 27% of all fatal two-vehicle accidents involved older drivers turning left (NHTSA, 2001).

Faulkner (1975) investigated driver age and junction accidents in England, which follows left sided traffic rules. Based on accidents per kilometre travelled, drivers between 45 and 54 had higher accident rates than those aged 35 to 44 for approaches to intersections from minor roads. Drivers 55 to 64 had accident rates twice the average of all drivers, and drivers 65 and older had a rate five times the average. Moore et al. (1982) expanded the scope of this study by using police reports from 1975 in England. Rates of two-vehicle right turn accidents were adjusted using travel (i.e., exposure) from the 1975-76 National Travel Survey. Drivers 65 and older had higher rates of two-vehicle right turn accidents. When differences between rural and urban junctions were analyzed, those 65 and older had a higher risk of right turn accidents in rural (2.59 times) than in urban (1.28 times) locations. In accidents where a "Give Way" sign (i.e., yield), stop sign, yellow light, or red light was disobeyed, older drivers emerging from a minor road were 2.5 times as likely to have disobeyed the traffic control. Overall, older drivers (65+) had about twice the number accidents as other drivers when cited for disobeying the traffic control. The highest rates were for collisions with young drivers (17-19, 5 times) and older drivers (65+, 4 times). The explanation forwarded by the authors is that the speed of traffic and the rapidity with which junction situations change cannot be compensated for by actions of older drivers. Thus, the information received and processed must be dealt with such that crossing and merging actions can be accomplished. In many other types of accidents, such as alcohol-related or at night, older drivers are under-involved relative to other age groups.

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[1] Recent accident literature has emphasized the older driver, although in terms of frequency, younger drivers have the overwhelming percentage of intersection accidents (Staplin & Lyles, 1991). In general, the accident profile of younger drivers, especially males, includes factors such as excessive speed, proneness to distraction, less experience anticipating hazards, and a greater willingness to commit stop sign and traffic signal violations. Alcohol, drugs, and nighttime driving are also frequent contributing factors.

Hauer (1988), using NHTSA data for 1985, found that 69,850 older drivers were injured and 995 were killed at intersections in the U.S. Of all the accidents and injuries for older drivers, 59.0% of fatalities and 36.7% of injury accidents occurred at intersections. The overwhelming majority of accidents (87.7%) occurred during the daytime hours. This is consistent with older drivers' self-reported reduction in nighttime driving (Chu, 1994). Older drivers aged 65 to 69 are 2.26 times more likely to be involved in a multi-vehicle accident at an intersection, and those aged 85 and older are 10.62 times more at risk than drivers in the 40 to 49 age group (Preusser et al., 1998). Over-representation of older drivers in intersection fatalities is due, in part, to their relative fragility when compared to younger drivers who can better tolerate the same collision forces (Evans, 1988; Hauer, 1988). Older female drivers appear to be over-represented in left turn accidents compared to their male peers (Stamatiadis & Deacon, 1998), although alternative statistical methods may yield different results if exposure is equated across gender (Massie et al., 1995; McGwin & Brown, 1999).

Garber and Srinivasan (1991) analyzed data sets concerning intersection accident data from 1986 to 1988 for the cities of Virginia Beach, Roanoke, Lynchburg, and Fredericksburg. Intersection accidents from the Virginia Department of Transportation (VDOT) were analyzed. The following data elements were used in their analyses: driver or pedestrian, intersection type, traffic control, weather, lighting, type of collision, vehicle zone of impact, causal factor(s), severity, driver gender, driver action, and vehicle maneuver. Accident involvement was calculated as "the ratio of the number of accidents for a given age group where there was a traffic violation to the total number of accidents for that age group in which there were no traffic violations" (p. 9). The number of intersection accident involvements for those 65 and above was significantly greater than for other age groups in the VDOT data set. The percentage of drivers involved in left turn accidents increased with age and VDOT data sets respectively. Left turn collision involvement for the 70+ age group appears to double over that of the 65 to 69 age group. Right turn collisions increased, but only slightly, in the oldest age group. Outside city areas, older driver involvement in intersection accidents increased. Angle collisions increased with age in both rural and urban environments as did failure to yield right of way. Women had significantly higher involvement ratios for intersection accidents than men across all the data.

Across all the accident patterns examined by Staplin and Lyles (1991), we have extracted those for left turn against traffic (LTAT) and crossing gap acceptance maneuvers as of particular interest for the present work. Staplin and Lyles used Michigan police-reported accidents from 1986 to 1988, which were subdivided by accident maneuver type, environmental conditions, location, severity, driver age group, and time of day. Relative involvement ratios were coded by "Driver 1 (D1) as being more at fault or causative of the accident and Driver 2 (D2) as less at fault" (p. 26). A left turn accident was defined as, "one of the two drivers in an accident was turning left" (p. 27). Signalized and non-signalized intersections and number of lanes were not separated in this work.

Of the 15,500 left turn accidents analyzed by Staplin and Lyles (1991), 69% occurred when D1 was turning left and D2 was going straight; 12% were where D1 was going straight and D2 was turning left; 8% happened while D1 was passing and D2 was turning; and 5% occurred as both drivers were turning. In the two most common accident configurations, task differences may account for a ten-fold difference in occurrence. When D1 is turning left and D2 is going straight, D1's task is to determine whether an adequate gap exists to turn through. D1 must judge the arrival of the oncoming vehicles while keeping track of cross traffic, vehicles ahead and behind, pedestrians, and the status of the traffic lights. In contrast, when D1 is going straight and D2 is turning, the turning vehicle (D2) is easier to see because a larger surface area is shown during the turn than when oncoming, although it may be surprising to D2 that D1 is violating D2's right of way. If D1 is at fault (i.e., does not have the right of way) he or she may not have seen the traffic light or stop sign. Not surprisingly, younger drivers under the age of 26 are over-involved in this type of accident, which is consistent with a lack of experience, inattention, or greater propensity for risk taking behaviours (McGwin & Brown, 1999).

Older drivers are more likely to be involved in left turn against traffic (LTAT) accidents during non-rush hour periods. Older drivers often choose not to drive during rush hour and in areas of high congestion (Chu, 1994). Time of day cross-tabulations indicated that 75% of left turn accidents happened in the daytime, 20% were at night, and 5% occurred at either dawn or dusk. Seventy percent of accidents were on dry pavement and 80% occurred on clear or cloudy days. Slightly more than half (56%) of accidents were classified as urban. Most accidents involved automobiles (80%) and, to a lesser extent, trucks (12%). However, in this latter category, no over-representation was found for truck involvement in left turns.

Older drivers showed consistent over-representation in left turn and crossing gap acceptance relative to all other age groups based on the ratio of D1 to D2 where D1 is more at fault (see Figure 2.1). Crossing gap acceptance accidents were defined simply as different crossing manoeuvres other than turning left. Within the older driver age group, there was also a significant difference in involvement between LTAT accidents and crossing gap acceptance accidents. Wallace et al. (1996) also found this pattern of left turn accidents using data from Arizona in 1988, once annual miles travelled were adjusted. In terms of frequency, however, younger drivers are the most involved in left turn accidents (Staplin & Lyles, 1991). Cross-tabulations of crossing gap accidents indicate that time of day and road conditions were similar to those for LTAT accidents.

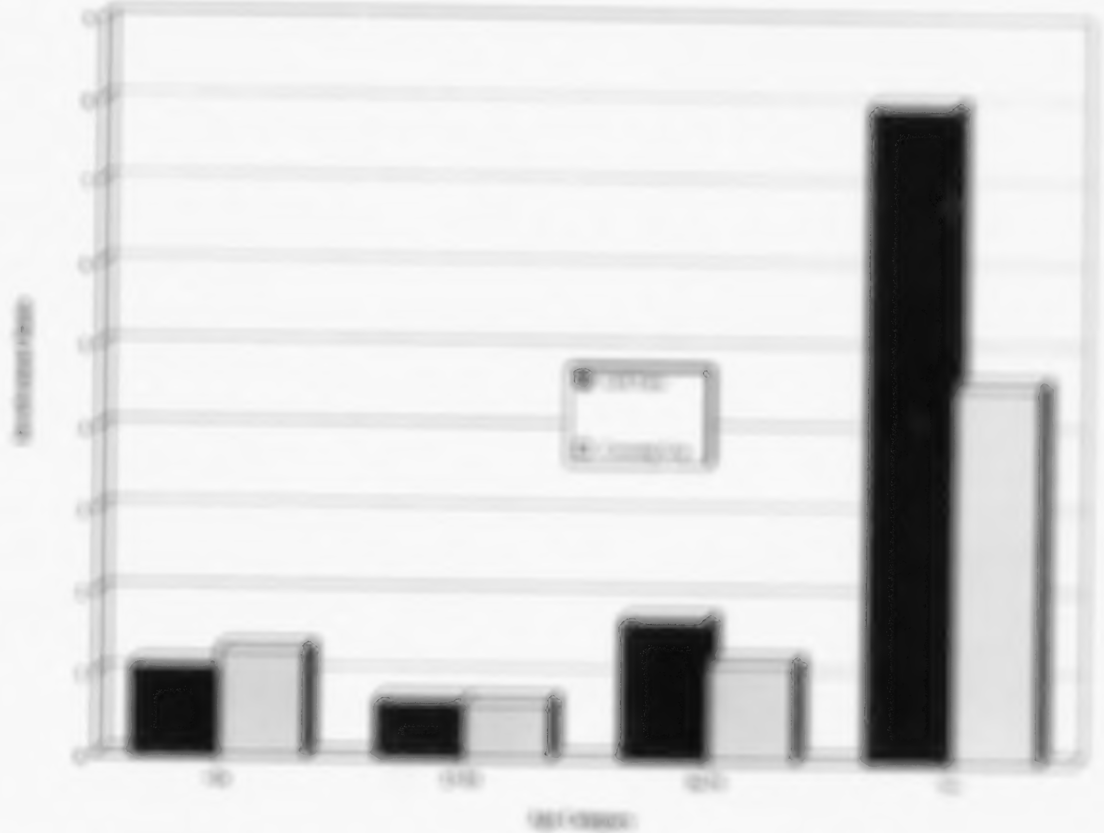


Figure 2.1. Involvement ratios by age group for LTAP and crossing path accidents. Adapted from Staplin & Lyles (1991), Tables 5 and 7 (pp. 28-29) and Garber & Srinivasan (1991).

Overall, older drivers per unit exposure are at greater risk for involvement in multi-vehicle collisions at intersections (Preusser et al., 1998; Stamatiadis & Deacon, 1996). Preusser et al. (1998) used data from the Fatal Accident Reporting Survey (FARS) between 1990 and 1995 to develop accident types for older drivers at intersections. An involvement ratio was calculated by dividing the number of involvements of one age group with a comparison age group (i.e., 40 to 49). About 80% of all intersection fatalities involved drivers aged 75 and older turning left, in contrast to 7% for those aged 40 to 49. "Fail traffic control" was the single largest accident type for older drivers at intersections and accounted for approximately one half of all fatalities for those 75 and older. Prior to the Preusser et al. (1998) study, it was known that older drivers have a higher risk of left turn accidents. However, their study shows that left turn risk is but one of many intersection maneuvers that are problematic for older drivers.

For example, Table 2.1, adapted from Preusser et al. (1998), shows the relative risk of accident involvement where the driver has failed to yield. "At stop sign" and "no traffic control" have the highest risk, while risk was lower for "turning left" and "at traffic lights." The accident categories of "at stop sign," "no traffic control," and "other maneuvres" have the highest relative risk, which increases with driver age. "Other maneuvres" included starting up from a stop sign. Clearly, *older drivers—especially those 75 years and older—have difficulties coping with the complexity of dynamic traffic interactions and traffic control information at intersections.*

Table 2.1. *Relative risk in "ran traffic control" cases (FARS 1994-1995). Adapted from Preusser et al. (1998, pg. 157, Table 5).*

	Driver age				
	65-69	70-74	75-79	80-84	85-up
All intersection	2.16	5.01	15.50	17.74	33.71
At traffic light	(0.91)	2.92	7.58	14.58	11.93
At stop sign	(2.41)	5.68	11.96	23.27	61.97
No traffic control	9.00	10.50	126.00	24.00	53.40
Going straight	(0.73)	3.50	12.14	13.21	26.72
Turning left	(0.89)	(1.45)	(1.91)	(2.45)	4.38

Note: None of the 95% confidence intervals surrounding the risk ratios shown in this table includes the value 1.00 (except for those ratios shown in parentheses). Therefore, each indicates a significantly greater risk for the respective older driver age groups relative to drivers aged 60-64.

2.2 Accident Contributing Factors

A number of broad categories of driver error have been used to describe the increased involvement of older drivers in accidents. Left turn and oncoming accidents typically involve a police citation for failure to yield the right of way (Retting et al., 1995). Older drivers tend to be more involved in intersection accidents where the driver is at fault (Garber & Srinivasan, 1991; Hakamies-Blomqvist, 1994; McKelvey et al., 1988; Viano et al., 1990). They were more frequently charged for failing to yield the right of way and turning illegally than any other age group (McKelvey et al., 1988). Generally, older drivers are more likely to not see signs and signals, whereas younger drivers are more likely to willfully violate traffic controls. Older drivers are more likely to commit a traffic violation at a stop sign as opposed to other traffic control devices (Garber & Srinivasan, 1991). *Table 2.2*, adapted from Preusser et al. (1998) shows that the percentage of "ran traffic control" increases from 35% for the age group of 70 to 74 to 53% for those 75 to 79. Other accident types remain relatively constant such as "stopped/stopping" while others such as "ran-off road" and "straight oncoming" decrease slightly with increasing age.

Table 2.2. Intersection accident types (FARS 1994-1995, passenger vehicles). Adapted from Preusser et al. (1998, pg. 157, Table 4).

	Percentage by driver age					
	40-49	*65-69*	*70-74*	*75-79*	*80-84*	*85-up*
	N = 661	*N* = 188	*N* = 200	*N* = 164	*N* = 243	*N* = 1,164
Ran traffic control	36	37	35	53	56	57
Ran off road	17	15	16	13	8	12
Straight oncoming	20	20	15	13	15	8
Stopped/stopping	7	9	8	4	5	6
Other	20	19	26	17	16	17

McGwin and Brown (1999) argued that the speed differential between older and younger drivers can cause hazardous conflicts. Hesitancy, relatively lower speeds, and erratic manoeuvres by older drivers may confuse other drivers at intersections. These actions, added together with a simple increase in response latency can result in dangerous situations (Hakamies-Blomqvist, 1994). Failure to anticipate the movement of other vehicles in the intersection may also contribute to driver errors and accidents (Treat et al., 1979).

Drivers must execute a number of tasks as they approach and negotiate an intersection (Caird & Hancock, 2002; Staplin et al., 1997; Tijerena et al., 1994). Traffic lights, traffic signs, and cross streets indicate the presence of an intersection. The right of way control must also be detected and interpreted correctly. Crossing and oncoming vehicles that are in or approaching an intersection must be detected and anticipated. The geometry of the intersection (i.e., the crossing angle of the roadways), the number of lanes, the presence of crosswalks, and the degree of traffic control affect how and when turns can be made at an intersection. Task failures can result in driver errors. A variety of errors have been identified specific to intersection accidents. Frequently, causal factors that may lead to an accident are multiply determined (Treat et al., 1979). In particular, Chovan et al. (1994, p. 4) re-analyzed the McKnight and Adams (1970) task analysis of left turns to identify a variety of driver errors that might precipitate left turn accidents. In addition, Caird and Hancock (2002, p. 631) identified a number of additional intersection errors in the literature, including:

- inadequate slowing before entering the intersection;
- failure to sense or comprehend traffic signals or signs;
- failure to anticipate the actions and/or intentions of other drivers and pedestrians;
- failure to detect an oncoming or crossing vehicle;
- failure to accurately judge the gap/velocity of an oncoming vehicle;
- physical masking of oncoming or crossing vehicles by other vehicles already in the intersection;
- obscured line of vision by vehicles in front of the driver;
- failure to coordinate travel within the intersection in accordance with the timing of the lights;
- weather-related problems and road conditions;
- roadway geometry limiting sight distances;
- driver impairment due to loss of capability, illness, drugs, fatigue, or alcohol;
- improper signalling;
- driver distraction by internal or external factors;
- poor manoeuvre execution (i.e., too fast or slow, wrong trajectory); and
- driver impatience or hurry.

A number of the errors listed above, such as impatience and impairment due to alcohol, are more likely to be committed by younger drivers. Other errors, including failure to sense or comprehend traffic signals or signs and impairment due to illness, are more likely to be committed by older drivers. Performance declines that result in the failure to detect, understand, decide or act upon traffic signs and signals require greater understanding.

Figure 2.2 summarizes likely accident precursors for older drivers at intersections. The lack of time to process and decide on a course of action has been advanced by a number of researchers to explain the commission of errors by older drivers (Hakimies-Blomqvist, 1994). Missed signs and signals by older drivers, precursors that increase with age, are specific behavioural contributors to increased intersection accident risk (Preusser et al., 1998). Urban and rural locations and daylight hours have been identified as somewhat more common to older driver intersection accident conditions (Staplin & Lyles, 1991). Above the age of 75, risk of intersection accident involvement rises dramatically. Illnesses that affect vision, cognition, and action increases accident risk in general. The actions of older drivers at intersections may be difficult to interpret by other drivers (McGwin & Brown, 1999).

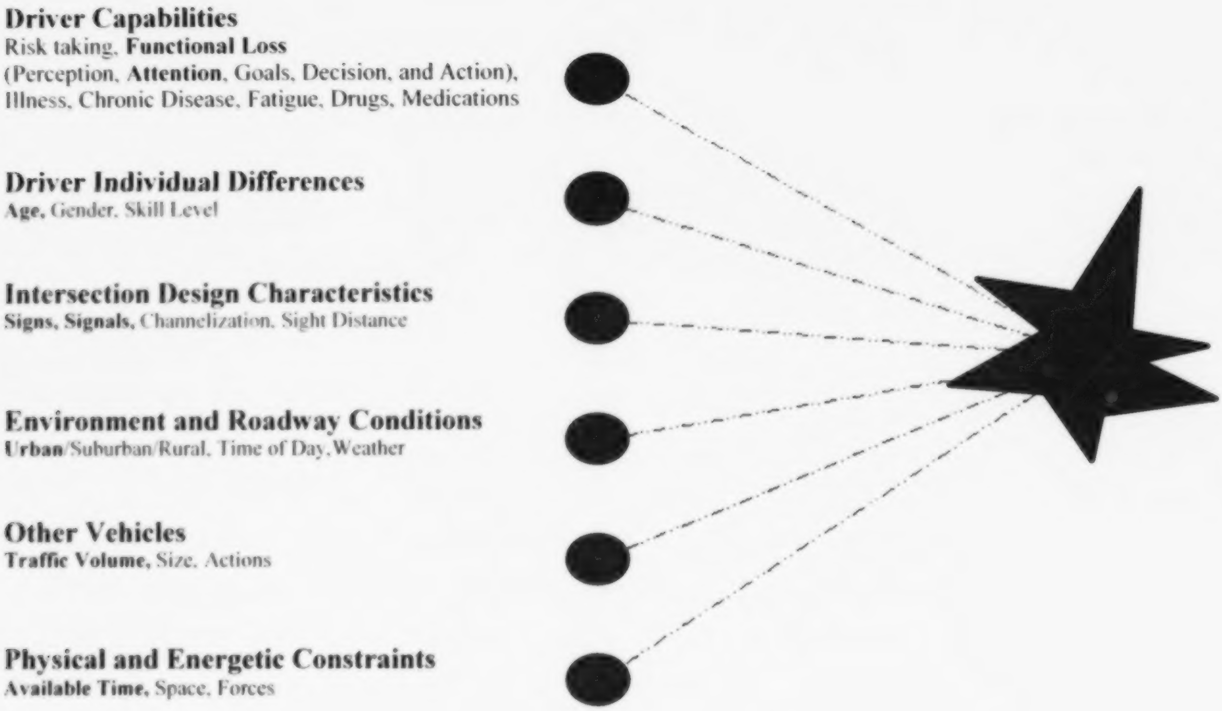

Driver Capabilities
Risk taking, **Functional Loss**
(Perception, **Attention**, Goals, Decision, and Action),
Illness, Chronic Disease, Fatigue, Drugs, Medications
Driver Individual Differences
Age, Gender, Skill Level
Intersection Design Characteristics
Signs, Signals, Channelization, Sight Distance
Environment and Roadway Conditions
Urban/Suburban/Rural, Time of Day, Weather
Other Vehicles
Traffic Volume, Size, Actions
Physical and Energetic Constraints
Available Time, Space, Forces

Figure 2.2. Contributors to older driver intersection accidents. Based on the literature review, contributors that are in bold type were to found to be more likely to contribute to accidents for normal aging drivers. For example, signs and signals are often missed by older drivers who are cited for failing to yield right of way at an intersection accident.

2.3 Useful Field of View (UFOV)

Failures of perception, attention, cognition, and action are most often used to explain older driver over-involvement in traffic accidents. Perceptual theory argues that, through various degenerative processes, the visual system is less able to detect and/or process accurately the movement of oncoming and/or crossing traffic (Staplin, 1995). The division of attention among driving tasks such as braking, accelerating, signalling, turning, and monitoring other traffic presents a high demand on older drivers. Failures of attention are likely to result in not seeing the other vehicle at all or until it is too late to react appropriately (Rumar, 1990; Treat et al., 1979). Attentional failures may result from the improper division of attention (Ponds et al., 1988), visual search difficulties (McDowd & Shaw, 2000), and/or the switching of attention (Parasuraman & Nestor, 1991). Other researchers have suggested that slowed reaction time, which results from generalized slowing (Birren & Fisher, 1995) to changing traffic conditions, is an accident contributor (Hakamies-Blomqvist, 1994). A combination of declining visual, attentive, and action capabilities of elderly drivers can contribute to increased driver risk.

One set of attentional measures, useful field of view (UFOV), has been used to predict older driver accident involvement with modest success (Owsley, in press). A critical review of these studies raises a variety of methodological issues. UFOV measures the size of the visual area in which targets can capture attention during brief inspection periods (Goode et al., 1998). In contrast, Scialfa et al. (1987) define UFOV as "an index of the total visual field area from which target characteristics can be acquired when eye and head movements are precluded" (p. 14). Three sub-tasks comprise the test for UFOV: visual processing speed, divided attention, and selective attention. These task descriptions are consistent with the methodologies adopted by Ball et al. (1993) and Goode et al. (1998). (See Scialfa et al., 1994, for alternative task descriptions).

For the visual processing speed task, observers are required to identify a target that varies in duration (from 12.5 to 250 ms) in a central display. The target in this subtest is a silhouette of a truck or a car. Participants are categorized as having failed this subtest if they cannot achieve a 75% accuracy at the longest duration (i.e., 250 ms). For the divided attention task, two targets that vary in duration are presented simultaneously. Observers are required to localize the peripheral target (e.g., a stop sign) as well as identify the central target. Peripheral targets appear at any one of 24 locations along 8 radial spokes (at eccentricities of 10°, 20°, or 30°) (Owsley et al., 1991). Target localization is accomplished by identifying on which of the radial spokes observers saw the target appear. The selective attention task differs from the divided attention task in that the peripheral target is embedded in a field of distractors (i.e., boxes). Failure on subtests 2 and 3 is indicated by the inability of observers to successfully complete the central task and localize the peripheral target beyond the minimum 5° eccentricity at 250 ms duration. The composite score from the three sub-tasks is expressed as a percentage reduction of the UFOV (0% represents normal useful field). A reduction of 40% has been used as a pass-fail cutoff point (Ball et al., 1993) for the purposes of classification of safe or unsafe drivers.

Hennessy (1995), assessed the utility of five experimental visual tests for prediction of accident likeliness. The tests were administered to 3,669 licence renewal applicants with a minimum of 12 years' licensed driving experience. Visual Test Performance (VTP) was correlated with the driver's prior three-year collision record. The tests consisted of Pelli-Robson low-contrast acuity test, Smith-Kettlewell low luminance card, Berkeley Glare Tester, Modified Synemed Perimeter test, and Visual Attention Analyzer (UFOV). Participants also filled out a Driving Habit Survey (DHS) that evaluated driving habits and self-restriction strategies. The overall correlation of VTP and history of collisions was not significant for all of the age groups combined. Only VTP on the Modified Synemed Perimeter test showed a small significance of predictive power for the 26-39 age group. Scores on the Modified Synemed Perimeter test and the Visual Attention Analyzer (UFOV) were significantly correlated with collisions in the 70+ age group. Only after statistically controlling for age, gender, and exposure effects did VTP scores on the UFOV test significantly associate with collisions. Moreover, the VTP predictive rate, after statistically controlling for covariates, was increased when looking at only Snellen acuity test fails. Neither VTP nor age explained more than 7% of the variance in self-restriction recorded through the DHS. Tests that improved detection of poor VTP included the Pelli-Robson low-contrast acuity test and perception response time (PRT) as measured by the visual attention analyzer. Hennessy's recommendations included further large-scale studies to validate both the Pelli-Robson and PRT test methods, and standardized chart testing of the current DMV test (i.e., Snellen) for correct assessment and referral system.

The bulk of the useful field of view (UFOV) literature is devoted to demonstrating the utility of the measures in predicting at-risk drivers for motor vehicle accidents, especially older drivers (e.g., Ball et al., 1998; Goode et al., 1998; Owsley, McGwin, Jr., & Ball, 1998; Sims et al., 1998) and as a driver screening or evaluation test. Appendix A summarizes a number of UFOV studies conducted in the previous decade. For example, Goode et al. (1998) found that the UFOV tests could successfully classify accidenters and non-accidenters from a sample of older drivers 85.4% of the time. Owsley, McGwin, Jr., and Ball (1998), Sims et al. (1998), and Ball et al. (1993) reported similar findings. Chaparro et al. (1999) conducted separate analyses on the different subtests and found that the divided and selective attention tasks were significantly correlated with accident involvement. Owsley et al. (1998), in a similar analysis, found that only the divided attention sub-task was associated with increased accident risk. Overall, UFOV has been shown to be reasonably predictive of accident involvement by impaired drivers.

Although the predictive utility of UFOV is promising, much of the evidence in its favour is derived from the same sample set (or sub-sets) used in Ball et al. (1993). To date, convergent evidence from other research groups for the predictive utility of UFOV with older driver accident involvement is minimal (Schieber, 1994). For instance, Brown et al. (1993), in a technical report, found that the correlation between useful field of view scores and accident frequency was quite low (N = 1447; r = 0.05). Further research is advocated, especially if the aim is for UFOV to have implications in licensing policy for drivers. The UFOV studies reviewed frequently lacked methodological detail. For example, it is unclear what the exact verbal protocol for the subtests are (particularly for subtests 2 and 3, where multiple responses are required), how observer responses are input (i.e., button press or verbal response), and what the nature of the distracter stimuli (i.e., physical characteristics and proximity to target) is. The sufficiency of the UFOV stimulus as an approximation of the actual traffic environment has also been questioned (McDowd & Shaw, 2000; Schieber, 1994). Other variables may be more predictive of accident involvement (Rizzo et al., in press).

2.4 Change Blindness

The change blindness experimental paradigm has the potential to allow the systematic manipulation of certain elements of the traffic environment to determine whether selective attention and decision making are affected. The accurate and timely allocation of attention at intersections is critical to the detection and response to other vehicles, pedestrians, and traffic controls. Drivers' decisions and actions are tightly coupled to the detection and correct identification of potentially hazardous objects. Driver errors where vehicles, traffic signals, and signs are missed altogether or are seen and not acted upon require greater understanding. The common accident category of "looked but did not see" tends to be used to categorize these kinds of driver errors (Treat, 1980).

Change blindness is defined as the inability to detect changes made to an object or a scene during a saccade, flicker, blink, or movie cut (O'Regan et al. 1999, p. 34). Change blindness is especially pronounced when brief blank fields are placed between alternating displays of an original and modified scene. The *flicker paradigm* is often used to induce change blindness in observers (e.g., Rensink, 1998; Rensink et al. 1997, 2000) (see Figure 3). In the standard or generic application of this paradigm, an image (A) and a modified image (A') are presented for a short duration (typically 240 ms) separated by a blank field of 80 ms (i.e., the inter-stimulus interval or ISI). The images are alternated repeatedly until a response is made or a certain time has elapsed (e.g., 20 s). The sequence of image presentation can also be manipulated in a variety of ways (i.e., A, A', A, A' or A, A, A', A').

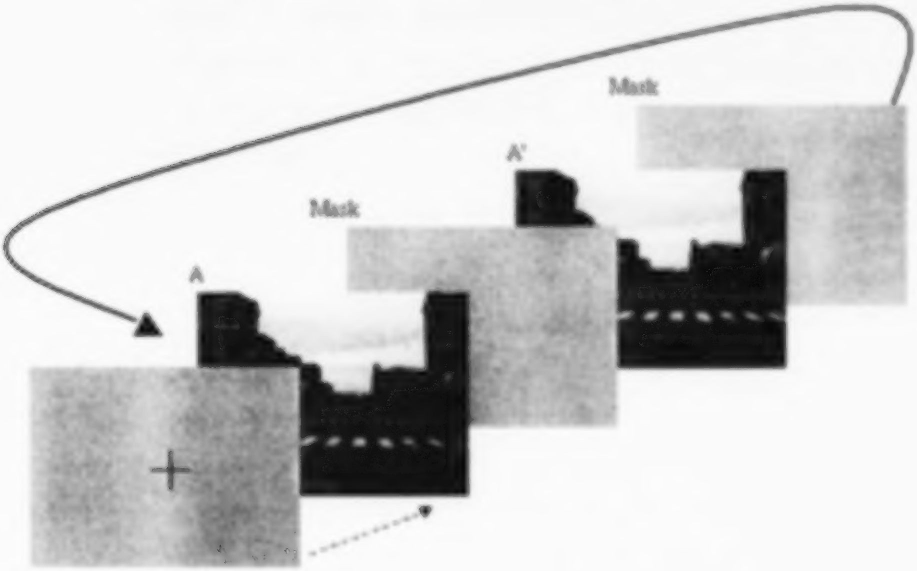


Figure 2.3. Generic flicker paradigm with fixation screen, A, mask, and A' shown.

The "change blindness" paradigm has implications for understanding how we construct, link, and store visual representations. The long-held view is that we store detailed and coherent picture-like representations of our world from one view to the next. However, recent results using the change blindness paradigm suggest that this may not be the case (e.g., Rensink et al. 1997; 2000;

Simons & Levin, 1997). For example, Rensink (2000a) suggested that focused attention provides spatio-temporal coherence for the stable representation of a single object at a time. In his theory, attention is coordinated in the creation of a "virtual representation" wherein stable representations of objects are formed whenever needed. If attention is required to construct stable object representations, maintenance of multiple hazardous objects is critical. In situations that are mentally demanding, such as a busy or complex intersection, the observer may not be able to adequately construct a stable and coherent representation for all of the important hazards. Objects such as other vehicles or pedestrians may be dropped from the representation of the scene as other objects are encountered.

Simons and Levin (1997) reviewed research that explains the phenomenon of change blindness. The capacity to attend to an object that undergoes a change while the eyes are moving from one location to another (i.e., a saccade) is discussed as having similar effects as the flicker paradigm. Saccades and focused attention elsewhere can produce change blindness-like effects. Research to date has addressed image changes that have varied in terms of presence, location, or colour. Appendix B summarizes most of the change blindness studies conducted to date. Manipulations of presence involve objects that appear in an image that were previously absent (e.g., a pedestrian appears in a previously vacant crosswalk). Location changes involve objects that move from one part of a scene to another across images, and colour changes involve alterations in hue or shadowing in the images. In addition to these changes, Rensink et al. (1997) also classified changes in terms of interest level. In their study, a group of independent observers viewed the scenes *a priori* and gave brief verbal descriptions of the images. Objects of central interest were described by the majority of observers, whereas objects of marginal interest were mentioned by none. Results showed that changes of marginal interest were very difficult to detect compared to changes of central interest. In the same study, Rensink et al. (1997) also investigated the effects of cueing on the detection of changes. They presented observers with a brief cue at the start of each trial that indicated in which part of a scene the change would occur. Cues were either valid or invalid. An invalid cue would indicate a change in one portion of the screen while the actual change takes place in another. Not surprisingly, the presentation of valid cues improved detection times for all change types while the presentation of invalid cues yielded slightly longer response times.

Rensink et al. (2000) further investigated change blindness through different manipulations of the flicker paradigm. In this study, they varied the duration of the inter-stimulus interval (ISI) from 40 to 300 ms. They found that the detection of change is faster for shorter duration ISI than for longer intervals, and change blindness is virtually non-existent when no ISI is present (*i.e.*, alternating images are flashed in immediate succession). Rensink et al. (2000) also manipulated the amount of coverage the ISI imposed on the scene. They compared a complete blank field (*i.e.*, one that covers the whole scene) to reduced coverage ISI wherein a series of blank patches flashed on the screen at random locations (though the patches, or "mud splats", did not occlude the change that was occurring). Reduced coverage during ISI still resulted in change blindness, though detection was improved compared to full coverage.

Pringle (2000) investigated change blindness in older adults and its relation to useful field of view (UFOV). Groups of younger and older adults were subjected to UFOV and change detection tasks. Results showed that detection of changes was more difficult for older than younger adults. In addition, a smaller UFOV was associated with slower detection of changes.

If focused attention on hazardous objects is required to construct a coherent representation of a scene, as Rensink (2000a) suggests, it follows that intersections that have increased complexity, traffic flow, and visual clutter will also have a higher incidence of missed (*i.e.*, failed to detect) objects. Though accident statistics cannot directly support or disprove any theory of attention *per se*, intersections are problematic for many drivers. Older drivers, in particular, may be at risk in such situations where attentional demands are taxing. If older drivers can only attend to (*i.e.*, construct a coherent representation of) a limited number of environmental features, then high-demand intersections may prove overwhelming and hazards may go unnoticed.

2.5 Cognitive Decline and Compensation Strategies

Cognitive deficits that affect older drivers' abilities to perform under certain road conditions are well documented. Delorme and Marin-Lamellet (1998) and Guerrier et al. (1999) showed that older drivers experience difficulties in complex traffic situations, especially when forced to make decisions in limited periods of time. Delorme and Marin-Lamellet hypothesized that working memory deficits contributed to the mistakes older drivers made in time-controlled, complex situations. Deficits in working memory possibly slow down an individual's reaction time so, when they only have a limited amount of time in which to act, they act without the opportunity to assimilate and process all the information needed to make a correct decision. Guerrier et al. also showed that working memory possibly mediates the amount of time needed to make a correct decision for older drivers, and that drivers with higher working memory capacity may actually take longer to make a decision in a complex situation than those with lower capacity. In a study of older female drivers, they found that those with lower working memory capacity made quicker decisions in a left turn scenario, but made fewer correct decisions, than those with a higher capacity. Presumably, not being able to assimilate all the information means an individual spends less time processing information to make a decision, which would explain why individuals with lower working memory capacity made faster decisions.

Wolffelaar, Rothengatter and Brouwer (as cited in Delorme & Marin-Lamellet, 1998) found that elderly drivers required more time than younger drivers to make merge decisions. In their study, the less time older drivers had to make a decision, the less likely they were to perform correctly and merge successfully. Verwey (2000) hypothesized that an increase in mental workload, defined as the amount of attention needed to make decisions, would more severely hamper older drivers' abilities to navigate complex driving situations than it would those of younger drivers. The older drivers he tested showed significant decreases in driving performance while completing a secondary task during complex road situations, such as intersections, roundabouts, and motorways, when compared with their younger counterparts. Based on this research, he suggested that older drivers possibly suffer deficits in attention and that extra demands on attention, which are present in complex road situations, could lead to a decrease in driving performance. Overall, working memory and attention appear to mediate older driver performance in time-controlled, complex situations.

These cognitive deficits may make travelling on urban roads difficult for the older driver, particularly as cities become busier and the junctions required to get from place to place more complicated. Holland and Rabbitt (1992) showed that many older drivers were not aware of their cognitive deficits and, therefore, did not change their driving habits to compensate for these deficits. Older drivers who are unaware of their deficits may increase the risk of collision, which may increase their risk on the roadway. Although older drivers were not necessarily aware of cognitive deficits, some were aware of sensory deficits and did engage in appropriate compensatory behaviours (Holland & Rabbitt, 1992). For example, some realized they had poor night vision and stopped driving at night. As well, once drivers were made aware of their sensory deficits, they were found to engage in compensatory behaviours, such as having prescription glasses updated. In a different survey to determine older drivers' perceptions of their driving performance, over half of the respondents said they no longer drove at night and 20% said they avoided complex junctions in their everyday driving (Holland & Rabbitt, 1994). In addition, 28% said they did not react as quickly as when they were younger.

Smiley (2002) explained how older driver adaptations might not necessarily keep them safe on the road. For example, many older drivers tend to drive more slowly than other traffic, either consciously or unconsciously. However, driving more slowly can put drivers at increased risk because they may not be able to successfully enter gaps in traffic when changing lanes or trying to merge. As well, the few adaptations older drivers engage in do not help them in complex traffic situations, like left turns. In fact, Staplin et al. (1997) noted that older drivers appeared timid while making left turns; they often did not pull into intersections to get a better view of oncoming traffic and reducing their travel distance across the intersection.

Overall, many older drivers remain unaware of their cognitive deficits and how those deficits affect their driving. It also appears that older drivers do not adapt effectively to the cognitive and sensory changes they experience as they age, particularly in complex situations. Because older drivers come into contact with complex situations on a daily basis, it is important to know which situations they find difficult while driving and whether they successfully adapt to these situations.

2.6 Hypotheses

Several hypotheses regarding older driver performance at intersections are plausible. Following is a list compiled from our literature review.

- Driver decision-making performance at intersections, which inherently have short and uncontrollable deliberation time and uncertain information, is worse for older drivers (Delorme & Marin-Lamellet, 1998).

- Age differences will be more pronounced as the complexity of the task increases (age × task complexity hypothesis) (e.g., see Salthouse, 1988). At intersections, more complex task demands will disproportionately affect older drivers than younger drivers.

- Older drivers, in general, need more time to process intersection information. Generalized slowing predicts more time will be needed to process intersection information.

- Older drivers process information as quickly as younger drivers, but are more cautious when they respond.

- Inhibitory mechanisms become faulty with age. Thus, older drivers are more likely to become distracted by elements of the traffic scene and miss relevant information (Hasher & Zacks, 1988).

- "Where" visual information that is relevant to safe passage through an intersection, such as the location of other vehicles, has a higher attentional priority than "what" information, such as processing the meaning of traffic lights and signs.

- An older driver may not be able to construct a stable and coherent representation for all the important hazards of an intersection, and critical ones may be dropped from working memory. Limitations of working memory are related to accident risk.

- As a function of the number of eye movements an older driver makes, the probability of detection of important information decreases.

- Older drivers, when aware of the loss of driving capability, will adjust their risk by adopting compensatory strategies.

3. FOCUS GROUP STUDY

3.1 Introduction

In this study, older drivers were recruited to participate in focus groups to discuss difficulties they had driving in Calgary. The objective of the focus groups was to gather qualitative information about the types of difficulties experienced by older drivers and whether older drivers engaged in adaptive behaviours. It was expected that older drivers would have more complaints about situations requiring an increased level of attention or about situations where time limits force drivers to make decisions quickly, such as unprotected left turns and merging. The study attempted to confirm the hypothesis that older drivers experience more problems at complex intersections and impose self-restrictions when made aware of poor performance. Finally, the focus groups were designed to gather data on particular intersections in Calgary where older drivers experience problems.

3.2 Focus Group Methods

A focus group is an informal discussion group of 8 to 12 heterogeneous volunteers. A facilitator (i.e., the Principal Investigator) guided the discussion of the group. Topics of discussion included: general driving patterns (e.g., nighttime, in bad weather, during rush hour); general perceptions of changes in Calgary traffic; specific individual mobility challenges (e.g., seeing and understanding particular signs and traffic control devices); specific intersections that are perceived as more or less challenging; general strategies to overcome traffic environment problems (e.g., driving with a companion, not driving at certain times and under certain conditions, adopting a deliberate, slow driving style, etc.).

To elicit specific examples of driving difficulties, the critical incident method was used during the focus group process (Flanagan, 1954). The critical incident method asks people to recall, within the past several months, specific situations where they had either success or difficulty executing a traffic manoeuvre. Volunteers could either talk about, write about, or not share their experiences. To bring closure to each focus group, discussions were directed toward information and services (e.g., Alberta Motor Association) that can help older drivers maintain their mobility. Several observers recorded the comments made by participants during the discussions.

individuals were not identified by name. In addition to these open discussion questions, participants were asked to fill out a background driving questionnaire (Appendix D) and the Driver Behaviour Questionnaire (Appendix E). Each of the two focus group sessions lasted about 75 minutes.

3.3 Participants

Drivers over the age of 65 were recruited by advertising in the Kerby News, the newspaper of a large senior citizens' centre in Calgary, the Kerby Centre. Seventeen seniors (6 men, 11 women) volunteered for the focus groups, which took place in a room at the Kerby Centre. Two separate focus groups were conducted; 9 were in the first group and 8 in the second. Fourteen of the 17 participants completed the Driver Experience Questionnaire, which was used to gather the following demographic data: age, gender, visual status, years of driving experience, number of kilometres driven per year, number of moving violations in the past two years, number of accidents, and where and how often participants drove.

The average age of the participants was 74.9 years (range 66-87) and the mean total of driving experience was 50.5 years (range 45-59). All participants held current driver's licences and the average number of kilometres driven per year was 13,750. Overall, group members drove at least once or twice weekly and mostly on city roads. Nine participants wore glasses to correct their vision while driving (two single-vision prescriptions, four bifocals, three trifocals). Two participants had degenerative eye diseases (one glaucoma, one macula hole). None of the participants reported using medications that might affect their ability to drive.

3.4 Procedures

Each participant filled out an informed consent form before discussion began (Appendix C). Participants were told that discussion would concentrate on the difficulties that older and younger drivers experienced at intersections. They were also told they could contribute as much or as little as they liked during the discussions. A set of open-ended questions, which were based on the literature (see Sections 2.2 and 2.5), was used to guide discussions. The questions used in the first focus group were modified so that more specific responses could be elicited. Focus Group 1 and 2 questions appear below.

Focus Group 1 Questions

1. How much has driving in Calgary changed over the years?
2. What conditions make you feel uncomfortable while you're driving?
3. Can you think of an incident you've experienced or observed that was troublesome?
4. Can you describe what makes an intersection good or bad?
5. Is there anything you do to keep up with driving changes or to stay safer on the road?

Focus Group 2 Questions

1. What makes you uncomfortable when you're driving?
2. Has there ever been a time when you needed to drive, but you chose not to because you felt uncomfortable going out on the road?
3. Can you describe in detail a time when you deliberately drove out of your way to avoid a certain type of road condition?
4. Can you think of an incident you've experienced or observed that was troublesome?
5. Can you describe intersections you find difficult to navigate in Calgary and why?
6. What steps do you take to keep your driving skills current or to make yourself feel safer on the road?

At the conclusion, participants were given a debriefing form that described the purpose of the study (Appendix F). At the end of each focus group, participants were asked to fill out a 48 question Driver Behaviour Questionnaire (DBQ) (Appendix E). The DBQ was developed by Reason et al. (1990) to distinguish between a number of types of driver errors. Modified versions of the DBQ were administered by Åberg and Rimmö (1998), Blockey and Hartley (1995) and Caird and Kline (2000) to distinguish between slips, mistakes, violations, and organizational errors in a variety of driver samples. The DBQ in this study was used to determine the relative frequency of errors made by older and younger drivers at intersections. The original DBQ was extensively modified based on an intersection task analysis and compilation of errors at intersections (see Caird & Hancock, 2002). The DBQ was administered across all three studies (*i.e.*, focus groups, change blindness, and driving simulation). However, factor analysis and path analysis of the DBQ is not within the scope of the present report. Understanding the relationships between the frequency of reported at-risk intersection behaviours, such as red light running, and the involvement of individuals in accidents will be performed once a sufficient sample of drivers is acquired (200+).

3.5 Results

A complete listing of focus group comments can be found in Appendix G. Results are organized by question. Similar answers across the two focus groups are combined.

How much has driving in Calgary changed over the years?

Participants unanimously agreed that driving in Calgary had changed dramatically over the past 30 years. Even those who had only been in Calgary for several years had noticed an increase in traffic. Most felt Calgary's road infrastructure was not keeping up with the growth of the city. Similarly, many felt the public transit system was not adequately keeping up with the city's growth either, making travel by both car and public transit difficult. A number of participants felt Calgary's climate makes driving difficult, particularly when ice and snow are present.

What (conditions) make(s) you feel uncomfortable when/while you're driving?

Traffic manoeuvres that required drivers to merge into traffic or cross several lanes of traffic were the major issue of concern in this group. Some felt that merge lanes were too short to merge successfully. A few said they often had to merge onto one road and then immediately cross several lanes of traffic to reach their exit further up the same road. Missing exits was a shared concern. One participant admitted to driving miles out of her way to avoid merging. Driving in rush hour or heavy traffic made some participants uncomfortable, as did driving at night.

Some felt uncomfortable changing lanes, overtaking other traffic, and keeping up with the flow of traffic. Roads where two-lane traffic is forced into one lane after a traffic light were of concern to some. Many in the second focus group had had a bad experience with left turns, and in particular with unprotected left turns. One person mentioned a difficult hill in her neighbourhood where stopping in winter might mean not getting started again on the icy road. One person said driving at night was a problem and a few said they felt uncomfortable when the flow of traffic was above the legal speed limit. Specifically, they felt pressure to keep up with the traffic even though they did not feel safe. One driver said she did not feel comfortable driving after having not driven for several days or weeks. Many disliked driving behind large trucks or vans that impeded their view of the road ahead.

Has there ever been a time when you needed to drive, but you chose not to because you felt uncomfortable going out on the road?

Participants detailed a number of events they had observed or experienced that they found to be of concern. One woman witnessed another elderly woman pull into the "X" zone at an LRT (Light Rail Transit) crossing and the gate came down on the roof of the woman's car. When the witness got out to see if the driver was OK, the driver admitted to not knowing what the "X" meant. One driver described driving east on McKnight Boulevard N.E.: after crossing the lights at 36 Street N.E., the two-lane road quickly narrows to one without enough advance warning. Cars in the right lane often have to wait until all the cars in the left lane go by before being able to change lanes and continue. One driver recalled an incident he witnessed the morning of the focus group while stopped at a red light on Memorial Drive S.E.: he heard a bang and saw that an elderly woman's car had been pushed into the intersection and turned 90 degrees so that she now faced the wrong direction in the road. The car that hit her drove off; she was okay and managed to drive off by herself.

One person ran into a road barrier after the truck he was following pulled quickly into the other lane to avoid it. He did not have enough time to change lanes or stop before hitting the barrier. Another driver was almost hit while turning left from 33 Avenue S.W. onto 14 Street S.W. This turn does not have an advance signal. One driver gets confused at Richmond Road and Sarcee Trail S.W. after leaving home; she often gets turned around because the roads are hard to follow and ends up heading back toward her own house instead of toward where she wants to go. The final incident involved a driver who frequently turns into the Taco Bell on 16 Avenue N.W. and Home Road. She can then turn around and drive straight across 16 Avenue on Home Road instead of trying to turn left onto Home Road without an advanced light.

A few people mentioned that dual left turns at controlled intersections were a general problem because drivers in the left turn lane often drifted into the right, cutting off the drivers turning from the right lane. They described 11 Street and 6 Avenue S.W. as a particular area where they experienced this problem; this intersection is only two blocks from the Kerby Centre. One couple often drives out of their way to avoid making a left turn onto a busy road that does not have lights in their neighbourhood. Instead, they drive through their neighbourhood to the next main road with lights so they can turn left with an advance signal. This means they must double back past their house on the other road after making the turn at the lights.

Can you describe intersections you find difficult to navigate in Calgary and why?

Participants had no trouble describing characteristics of intersections that either posed trouble for them or that they felt could pose trouble for others. Key examples included intersections where drivers were required to merge while going uphill and where drivers had to yield or stop before pulling into fast-moving traffic. Participants felt both these situations impeded being able to safely enter fast-moving traffic because they were forced, either by having to go uphill or yield, to slow down too much below the speed of the traffic they were trying to enter. Some people felt that some intersections had too many signs, which they found distracting when trying to figure out which way to go. Several felt signs were inconsistently placed from intersection to intersection and that some signs were difficult to read. No one mentioned any good intersections when asked.

The following intersections were considered problematic for the indicated reasons:

- Richmond Road and Sarcee Trail S.W.: confusing, too many roads (see Figure 3.1)
- 17 Avenue and 14 Street S.W.: no left turns allowed onto 17 Ave from 14 St in either direction
- Bow Trail and 33 Avenue S.W.: no protected left turn going west
- 17 Avenue and 8 Street S.W.: new parking meters on the right force drivers to switch quickly into left lane after the light; no advance warning that it narrows to one lane
- 19 Street and John Laurie Blvd N.W.: too difficult to make a left turn onto John Laurie because traffic is moving too fast and there are no lights
- 16 Avenue and Home Road N.W.: awkward left turn with no advance light

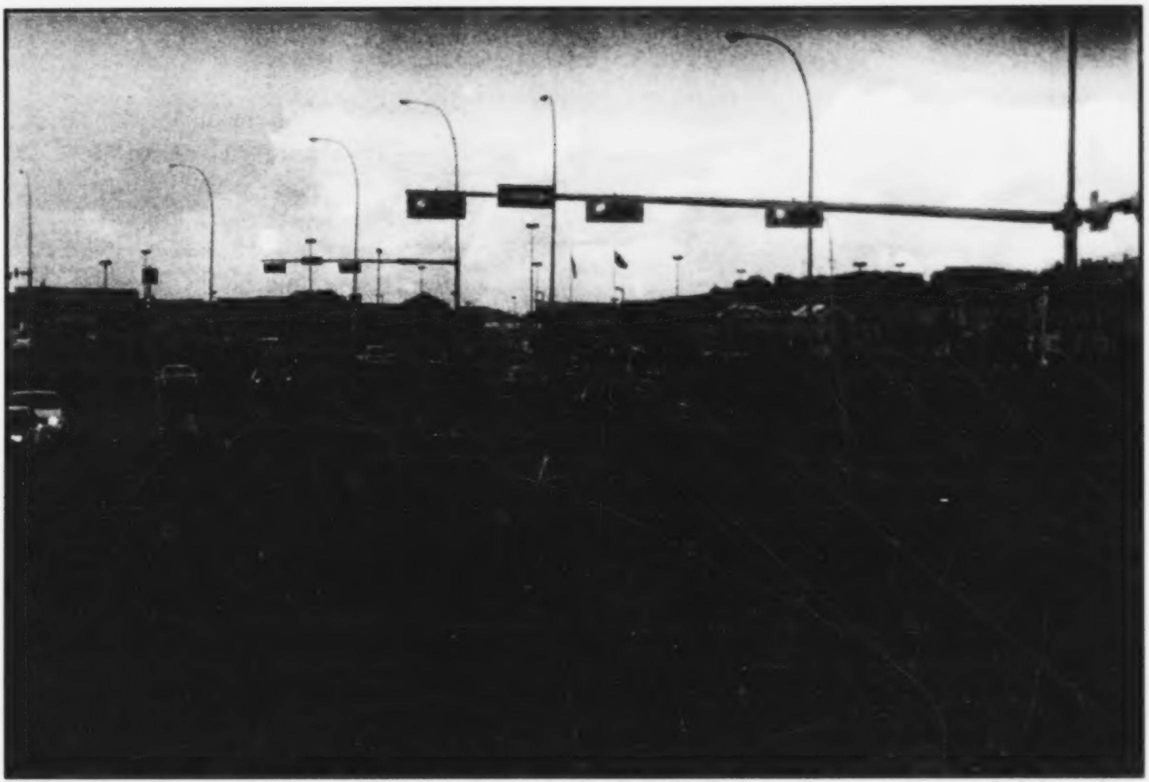


Figure 3.1. East on Richmond Road and Sarcee Trail S.W. Drivers incorrectly turn left into the opposing lanes of traffic, in part, due to signs, signals, and the overall complexity of the multiple intersections.

A number of participants said that sign size and placement at a variety of locations were not ideal. Stop signs were thought to be too far back from the intersection and certain signs, such as street name signs, were difficult to read. One person felt billboards were distracting when trying to read road signs and others said that trees or other obstacles obscured playground and school zone signs. One person preferred the left advance turn light to be on the centre pole rather than on the same pole as the red light. They felt a flashing green light next to the red was not as obvious because most drivers were looking at the red.

Is there anything you do to keep up with driving changes or to stay safer on the road?

A number of adaptations were described that helped drivers travel on Calgary's roads. Half of the second focus group said they now wait longer than they used to at green lights to ensure the intersection is clear before proceeding. Two participants no longer drove at night, while three said they chose not to drive during rush hour or during busy times if possible. Another person no longer drove at night because of tunnel vision; he also had his vision tested annually. One person no longer drove downtown. One couple drove to a controlled intersection to make a left turn because they felt uncomfortable making a turn at the uncontrolled intersection near their home. As mentioned previously, one woman said she would drive miles out of her way to avoid merging.

Three drivers took the Alberta Motor Association's (AMA) course for older drivers. Most of the drivers admitted to leaving early to arrive at their destinations in time and to avoid getting caught in traffic. One person said she gives herself a "pep talk" before getting on the road and then reminds herself to "stay calm and smart" while driving. Two women brought up incidences in which their family doctors would not declare their elderly fathers unfit to drive, even though the families felt the men should not be driving. A few people suggested that family doctors should not be responsible for deciding whether an elderly driver is medically fit to drive. They felt family doctors could not be impartial when deciding whether drivers should be allowed to keep their licence. Most people in this group also strongly supported the idea of regular drivers' tests for older drivers, although they could not pinpoint a specific age when testing should begin. One person felt after 80 would be a good time for regular testing. Most felt drivers' tests should include a medical test and that both types of test should be more strongly regulated by the provincial government.

3.6 Discussion

Overall, the drivers in the focus groups seemed to confirm known accident and behavioural patterns already reported in the literature. Older driver difficulties with complex road situations is documented in controlled and epidemiological studies (Caird and Hancock, 2002; Preusser et al., 1998). It was not surprising that left turns and merging were two major areas of concern for these drivers. According to these drivers, merge lanes were either too short or poorly designed to merge successfully. Some older drivers may require more time and distance in a merge situation to make a comfortable manoeuvre. Problems associated with left turns were due to busy roads, the absence of advance turn signals, and comprehensible signage. Some drivers seem to feel uncomfortable with merges and unprotected left turns and they opt to avoid these locations. For example, a few participants admitted to avoiding certain left turns – such as the couple who drive several extra blocks to reach a controlled intersection, or the woman who turns around at the Taco Bell so as not to make an awkward left turn – and one woman who will "drive miles" out of her way to avoid merging.

When the amount of time to make a decision is limited by the nature of the situation, greater performance decrements are expected (e.g., Guerrier et al., 1999; Delorme and Marin-Lamellet, 1998). Brouwer and Ponds (1994) suggested that intersections be designed so decisions are made sequencially rather than simultaneously. Older drivers have difficulties with working memory and attention in high mental workload situations (e.g., Guerrier et al., 1999; Verway, 2000). Brouwer and Ponds (1994) defined two areas of driver competence: driving skill and medical/physiological fitness to drive. They suggested driving skill was based on experience and found older drivers were often judged better in on-road tests than would be expected based on their neuro-physiological test results. Those suggestions support the focus group participants' desire for concurrent driving tests and medical tests to determine driver fitness. Participants also felt stricter regulations should be put in place. Better regulations combined with appropriate testing could help reduce the number of unsuitable drivers on the road.

Older drivers did not always seem to be aware of making errors while driving (Holland & Rabbitt, 1994). In an open-group format, older drivers did not admit to making many mistakes while driving. This might be because they are surrounded by a group of their peers and might feel pressure to be perceived a certain way, such as being a good driver. Social desirability theory suggests that most participants would like to be seen as a competent driver in a group setting. When drivers admitted to problems with certain driving conditions, like merging and turning left, they tended to attribute the problem to road design or other drivers (i.e., younger drivers) rather than any changes in performance they experienced as they aged. Many older drivers seem to be unaware of visual and cognitive declines as they age (Holland & Rabbitt, 1992). One reason for this might be that people are not good judges of their own level of competence, particularly when performance demands change from one environment to another (Rabbitt & Abson, 1990).

Only three people said they no longer drove at night and three or four chose not to drive during rush hour or in heavy traffic if they could avoid it. The single biggest adaptation this group of drivers made was waiting longer at a green light before starting up, to ensure the intersection was clear. A few chose to avoid complex intersections with which they had difficulties. A few drivers in both groups were interested in knowing what they could do to stay safer while driving; however, only three had taken a course for older drivers. The AMA's driver course is an in-class course and not an on-road course. Some drivers expressed a desire for on-road instruction. Although training is not likely to improve working memory performance or enhance other cognitive declines, training and practice might increase older drivers' understanding of their limitations on the road.

Focus group verbal reports are not suited to determine conclusively whether individuals recognize declines in their own performance. Caution should be exercised when their statements are interpreted. Overall, the focus groups outlined important areas for further research. This is in line with previous literature. Specific limitations of older driver intersection performance were the focus of the next research phase.

6. CHANGE BLINDNESS STUDY

6.1 Introduction

After age 75, the risk of intersection accident involvement for older drivers increases for most intersection manoeuvres. Failure to yield right of way and violation of traffic controls are common citations for older drivers. Previous research has argued that age-related declines in attentional breadth and switching can discriminate between those who are and are not more likely to be in an accident. It was expected that less time to decide, process, and act upon intersection decisions would adversely affect older drivers more so than younger drivers. The accurate and timely allocation of attention at intersections is critical to the detection and response to other vehicles, pedestrians, and traffic controls. Drivers' decisions and actions are tightly coupled to the detection and correct identification of potentially hazardous objects. Driver errors where vehicles, traffic signals, and signs are missed altogether or are seen and not acted upon require greater understanding. The common accident category of "looked but did not see" tends to be used to categorize these kinds of driver errors (Treat, 1980).

The change blindness paradigm was adapted to assess selective attention at intersections. Change blindness is defined as the inability to detect changes made to an object or a scene during a saccade, flicker, blink, or movie cut (O'Regan et al.1999, p. 34). The change blindness paradigm has implications for understanding how we construct, link, and store visual representations. The long-held view is that we store detailed and coherent picture-like representations of our world from one view to the next. However, recent results using the change blindness paradigm suggest that this may not be the case (e.g., Rensink et al. 1997; 2000; Mack & Rock, 1998; Simons & Levin, 1997). For example, Rensink (2000a) suggested that focused attention provides spatio-temporal coherence for the stable representation of a single object at a time. In his theory, attention is coordinated in the creation of a "virtual representation" wherein stable representations of objects are formed whenever needed. If attention is required to construct stable object representations, maintenance of multiple hazardous objects is critical. In situations that are mentally demanding, such as a busy or complex intersection, the observer may not be able to adequately construct a stable and coherent representation for all of the important hazards. Objects such as other vehicles or pedestrians may be dropped from the observer's representation of the scene as other objects are encountered. If focused attention on hazardous objects is required to construct a coherent representation of a scene, it follows that intersections that have increased complexity, traffic flow, and visual clutter will also have a higher incidence of missed (i.e., failed to detect) objects. The principal objective of the proposed research was to understand why drivers sometimes fail to detect critical hazards during intersection travel. In particular, the present study examined the effect of time constraints on older and younger driver intersection decisions. The participants, materials, tests, questionnaires, and procedures are described in greater detail.

4.2. Participants

Sixty-two older and younger adults were recruited from the following age groups: younger drivers (18 to 25), middle-aged (26 to 64), young-old (65 to 75), and old-old (76+). An equal number of men (8) and women (8) volunteered for each group except for the latter age group. Despite several months of concerted recruiting, we were unable to find enough women over the age of 76 who had continued to drive. Thus, 8 men and 6 women were in the 76+ age group. Older participants were recruited from senior community programs in Calgary, Alberta. Younger volunteers came from the Psychology Department's research participation pool at the University of Calgary. A valid driver's license and an active driving record were requirements for participation. All were screened for visual acuity and contrast sensitivity. At their discretion, older participants were paid either $15 for completing the study or a donation was made to the senior centre from where they were recruited. Younger participants were given two bonus credits toward their class marks in psychology. Middle-aged participants, who were often graduate students, received either $15 or two university parking passes.

4.3. Materials

4.3.1 Hardware and Software

Intersection photographs were captured with a Nikon CoolPix 950 digital camera and manipulated using Adobe Photoshop 5.5 on a Macintosh G3 computer. ToolBook was used to develop the software application that managed the presentation of images and collection of response dependent measures. The application ran on a 933 MHz Pentium III PC connected to an

Epson data projector (Model 730C). Image sequences appeared on a 1.5 m by 1.5 m screen (Model Da-Lite) positioned 3 m in front of participants, who were seated at a vehicle mock-up that was composed of a steering wheel, brake, and accelerator. Only the brake and accelerator provided input to the ToolBook application.

6.5.2 Driving Images

Digital pictures of signalized and non-signalized intersections were taken in and around Calgary, Alberta; Winnipeg, Manitoba; and Montreal, Quebec. Images were downloaded from the Nikon CoolPix 950 digital camera at an 800 × 600 resolution and manipulated using Photoshop. Approximately 2500 intersection approaches were captured in total. From these, a series of screening processes narrowed the intersections that were considered for use in the study. Images were selected on the basis of image quality, position of the vehicle relative to the intersection, image manipulation opportunities, and a variety of intrinsic image properties such as traffic control devices, signage, pedestrians, other vehicles and hazards. A total of 15 Calgary images, 12 Winnipeg images, and 9 Montreal images were used in the experimental phase. Pilot testing determined that few, if any, participants could reliably tell where each image was filmed.

In each pair of images (i.e., A and A'), one image was manipulated in Photoshop. Approximately 100 pairs of images were manipulated. The city, turn direction, location, the change that was added to A', the correct action, and notes can be found in Appendix M. After a series of pilot studies, the images that were used for the experiment were reduced to 42 image pairs (i.e., A and A'). Six of these were used for training and the remaining 36 were used for experimental trials. A table of the actual intersection images, the turn direction, whether a go or no-go response was appropriate, the change that was presented, and whether it was relevant to the turn can be found in Appendix I.

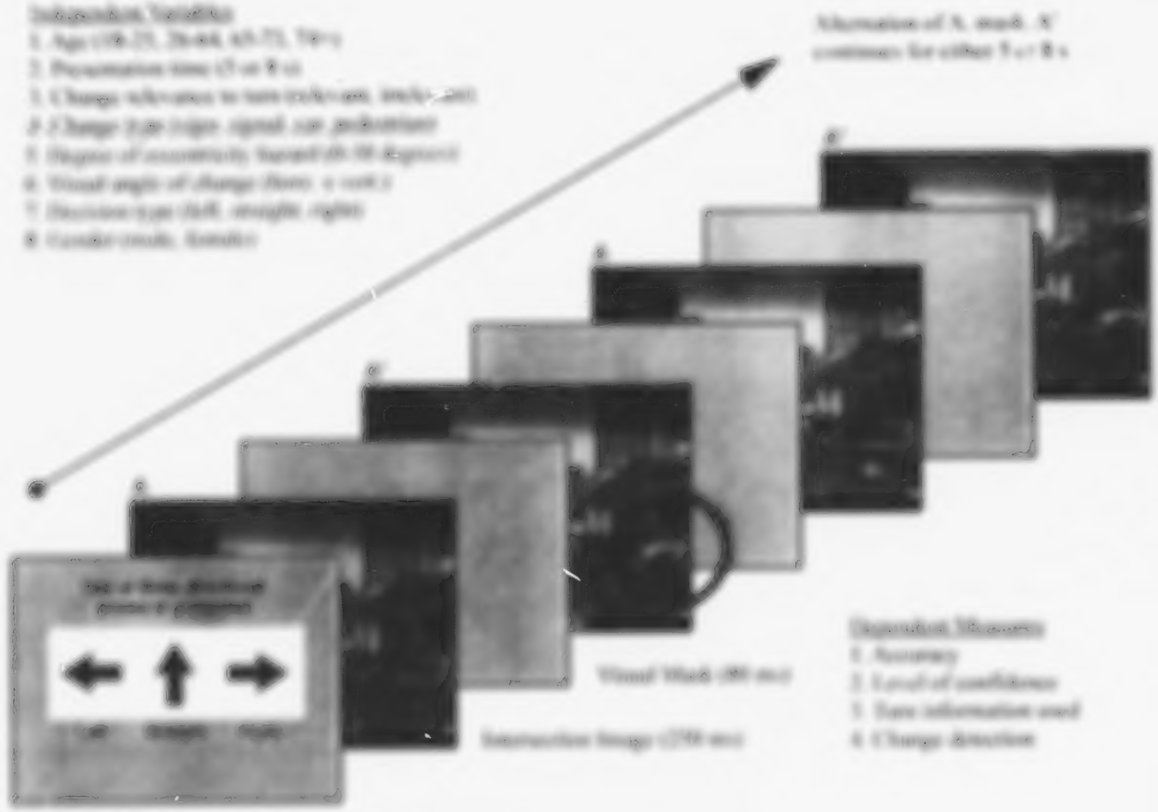
6.6 Procedure

6.6.1 Overall Testing Procedure

At the beginning of a 75 minute session, participants completed an informed consent form (similar to Appendix C) and a background driving experience questionnaire concerning age, gender, driving experience, and habits (see Appendix D). Visual acuity was tested at a distance of 6.1 m using Landolt Cs and contrast sensitivity was tested at a distance of 2.7 m using the Vistech Vision Contrast Test System. A short verbal overview of the tasks to be completed and practice trials were given to participants. Drivers were presented with 42 intersections that varied in complexity and changes within each (see Appendix M). Once participants finished the experimental portion of the testing, they completed the DBQ (Appendix E). They were then debriefed (similar to Appendix F) and remunerated for their participation.

6.6.2 Modified Change Blindness Paradigm

The "flicker" or "change blindness" method was modified so the tasks performed were more similar to those performed while driving. Typically, an original image and modified image are alternated repeatedly with blank fields presented between each successive image (Rensink et al. 1997). The principal difference of the present study was to begin each trial with one of three directional arrows that corresponded to the direction to turn left, turn right, or proceed straight ahead. Each was centred on a screen. The arrow indicated the desired direction of travel for the intersection that followed. For example, a left directional arrow indicated that a participant would be making a left-hand turn. Figure 6.1 illustrates the image, a modified image and blank screens.


Independent Variables
1. Age (18-25, 26-64, 65-73, 74+)
2. Presentation time (5 or 8 s)
3. Change relevance to turn (relevant, irrelevant)
4. Change type (sign, signal, car, pedestrian)
5. Degree of eccentricity hazard (0-30 degrees)
6. Visual angle of change (horiz. x vert.)
7. Decision type (left, straight, right)
8. Gender (male, female)
Alternation of A, mask, A' continues for either 5 or 8 s
A'
A
A'
A
Left
Straight
Right
Visual Mask (80 ms)
Intersection Image (250 ms)
Dependent Measures
1. Accuracy
2. Level of confidence
3. Turn information used
4. Change detection

Directions: Once you have memorized the turn direction, press button to start. At the conclusion of the presentation, press the accelerator if you would go or the brake if you would not go.

Figure 4.1. Modified flicker method with image sequence, independent and dependent variables, and participant directions. In this example, the taxi is not present in A and appears in A'. Participants were instructed to travel straight through the intersection. If they indicated that they would not go, their response was correct because the taxi was in their way.

Once the directional arrow was memorized, participants indicated that they were ready to start a new trial. Each image in a pair was presented for 250 ms with an inter-stimulus interval (ISI) of 80 ms (see Figure 4.1). A and A' continued to flicker back and forth for either 5 or 8 s. Once the intersection began to flicker, participants were instructed to decide whether they would go or not go in the direction that was indicated in the first screen. After the flickering stopped, a screen appeared that asked them to respond by pressing the accelerator to go, and the brake to not go.

Once they pressed either the brake or the accelerator, they were reminded to place their foot back on the ground.

After the decision to go or not to go was made, a screen appeared that asked the following four additional questions:

1) How confident are you in your decision to go or not to go?

2) State all of the elements (e.g., lights, other vehicles, signs, pedestrians) of the traffic scene that influenced your decision to go or not to go from the most important to the least important.

3) Did you notice anything changing in the images that you saw?

4) Did you make any assumptions about what you saw?

Participants completed a practice block consisting of six trials. The trials included all three directions of travel and several intersections where uncertainty was present in a decision. The interpretation of whether to go or not to go was placed on the participant. Including practice trials, a total of 42 pairs of images were presented to participants. A complete description of each intersection that was used is found in Appendix I. Participants were randomly assigned to one of two separate experimental orders (see Appendix K).

4.5 Results

4.5.1 Participant Characteristics

Results of the background driver experience questionnaire and visual screening tests are shown in Table 4.1. Mean age and standard deviations are shown. The number of years driving is also somewhat indicative of age. The number of kilometres driven per year is somewhat lower for the age group of 65 to 73 than the other age groups. The number of violations per year is highest in the 18 to 25 age group. The mean number of accidents for all age groups is between 1 and 2. The youngest age group had the highest mean number of accidents in the past five years. Corrected visual acuity and contrast sensitivity declined and was more variable in the two older age groups.

Table 4.1. Participant sample characteristics (means, standard deviations): mean age, number of years driving, kilometres driven per year, number of violations in the past two years, total number of accidents across all driving, accidents in previous five years, visual acuity, and contrast sensitivity.

Descriptive Measure	**Age Group**			
	18 to 25	**26 to 64**	**65 to 73**	**74 +**
Mean Age (SD)	21.75 (2.1)	38.81 (13.8)	69.25 (2.2)	78.4 (3.8)
Years Driving (SD)	5.13 (1.7)	20.56 (11.8)	47.5 (6.3)	53.1 (11.5)
Km/Year Driven (SD)	14,812 (10,8336)	15,013 (9,372)	10,718 (6,850)	13,285 (9,406)
Number of Violations, Last Two Years (SD)	5.13 (1.7)	0.2 (0.4)	0.2 (0.4)	0.36 (0.6)
Total Accidents (SD)	1.63 (1.4)	1.44 (1.1)	1.31 (1.2)	1.79 (1.5)
Accidents Last Five Years (SD)	1.5 (1.5)	0.5 (0.6)	0.65 (0.3)	0.36 (0.6)
Corrected Visual Acuity (SD)	20.1 (3.5)	20.1 (4.1)	21.4 (6.4)	29.3 (6.5)
Mean Contrast Sensitivity Values for Spatial Frequencies of 1.5, 3, 6, 12, 18 (cycles per degree)	70, 127.5, 125, 71.5, 26	70, 85, 125, 55, 15	70, 85, 97.5, 55, 10	62.5, 85, 57.5, 32, 10

4.5.2 Logistic Regression

The criterion data collected was a dichotomous variable called accuracy: participants could make either a correct or an incorrect decision at each of the 36 intersections. To analyze a dichotomous criterion variable, a non-parametric method called Logistic Regression (LR) was employed. LR provides a means to predict outcomes when using a set of variables that are continuous, dichotomous/discrete or a mixture (Tabachnick & Fidell, 2001). LR produces a log-linear function that describes results in a more complex manner than the usually understood methods (e.g., linear regression). Unlike parametric statistics, and because of the very nature of the outcome and predictor variables used in the present study, stringent assumptions about variables are not necessary. In the present study, LR provided a means to predict accuracy from two predictors, driver age (continuous) and time to view an intersection (discrete).

4.5.3 Accuracy Characteristics

The experimenters determined accuracy *a priori*. Accuracy was determined by whether participants correctly chose to go or not to go at each intersection. All 36 intersections were evaluated in terms of whether a decision to go would cause a collision or violate a traffic sign or signal. If a decision was correct, it was coded 1 and if it was incorrect, it was coded 0. Unique characteristics of each intersection, such as traffic control devices, vehicles present, pedestrians and so forth, confound collapsing accuracy across intersections. Each intersection is assumed to possess unique information that drivers use to determine whether to turn and, therefore, intersections were analyzed individually for effects.

A series of 36 direct (predictors entered simultaneously) LRs were computed using SPSS 11.0. The two predictors used were age and time; the outcome variable was decision accuracy. Time, being a discrete variable in the present study, was coded 0 for the 5-second interval and 1 for the 8-second interval. Age was used as a continuous predictor due to insufficient cell sizes across all age groups when left as a categorical variable. Insufficient cell sizes can lead to highly inflated parameter estimates, which, in turn, lead to erroneous results. The dichotomous outcome variable was accuracy: correct (coded 1) or not correct (coded 0). In total, 62 cases were entered into each of the LRs. Of the 36 LR analyses, 14 provided statistically significant predictions of accuracy. Age was a significant accuracy predictor in 10 intersections, time was a significant predictor for accuracy in 1 intersection, and both age and time were significant predictors in 3 intersections. Table 4.2 shows the intersection number, intersection description, chi-square value with all predictors (age and time) in the model, chi-square significance levels, predictors (age and time), coefficients (B), Wald statistics (W), and odds ratios (Exp(B)) for the 14 intersections. Significant intersections discussed in the analysis can be examined in Appendix M.

Table 4.2 Logistic regression of accuracy with driver age and time to view an intersection; intersection numbers, description and associated statistics.

Intersection	Description	$\chi^2(2)$	χ^2 sig. values	Predictors	B	Wald (z-ratio)	Exp(B) (odds ratio)
2	Yellow light, parked cars, pedestrians.	7.58	0.023	Age	-.034	2.32	0.967
				Time	-.882	1.32	0.414
5	Green light, left turning vehicle, pedestrian.	10.21	0.006	Age	-.034	2.78	0.967
				Time	.796	1.41	2.218
8	Stopped traffic, green light, pedestrian.	27.65	0.0001	Age	-.067	3.99	0.935
				Time	1.67	2.21	5.332
9	Clear intersection, pedestrian, green lights.	12.00	0.002	Age	-.037	2.89	0.964
				Time	-.964	1.67	0.382
12	Green lights, pedestrian, bicyclist.	33.03	0.0001	Age	-.087	3.98	0.964
				Time	1.89	2.18	6.633
13	Vehicles ahead, yellow light, oncoming turning vehicles.	4.457	0.045	Age	.001	0.11	1.001
				Time	1.31	2.00	3.711
15	Bus, no-left turn sign, green lights.	14.20	0.001	Age	-.044	3.37	0.957
				Time	-.584	0.97	0.558
21	Green lights, one-way, no-left turn sign.	18.28	0.0001	Age	-.142	2.24	0.868
				Time	-.272	0.33	0.762
23	Commercial truck, turning van, green lights, one-way sign.	8.17	0.011	Age	-.044	2.44	0.957
				Time	-.196	0.29	0.822
24	Traffic, pedestrian, pedestrian crossing lights.	12.43	0.002	Age	-.041	2.77	0.959
				Time	1.12	1.76	3.069
27	Vehicles ahead, one-way sign, green light.	15.60	0.0001	Age	-.034	2.56	0.967
				Time	1.75	2.86	5.758
29	Stopped vehicle, pedestrian, signs.	12.05	0.002	Age	-.043	2.84	0.958
				Time	1.01	1.49	2.735
31	Pedestrians, taxicab, green lights.	8.61	0.013	Age	-.033	2.78	0.967
				Time	.016	0.03	0.985
35	Turning vehicle, green lights, pedestrian.	13.89	0.001	Age	-.063	2.66	0.939
				Time	1.09	1.35	3.001

Notes: Wald values are significant if they exceed +/- 2. Significant intersection images can be found in Appendix M.

4.5.4 Intersection Decision Accuracy with Age as a Predictor

A description of each significant intersection, associated statistics, and a brief interpretation of each result is given next. Intersection 2 contained parked cars on both sides of the road, a yellow traffic control device, and pedestrians to the right, and did not have any changes associated with it. The researchers concluded the safest course of action was to clear the intersection because, from the participant's perspective, the vehicle had already entered the intersection. For intersection 2, the model with the two predictors, age and time, was statistically reliable, $\chi^2(2) = 7.58$, $p = 0.023$. According to the Wald statistic, only age predicted accuracy reliably $z = 2.32$, $p = 0.021$. The Wald statistic is a test of the individual contribution of a predictor to the model and follows a standard normal distribution. A value of +/- 2 was considered significant for the Wald test (i.e., a confidence interval of 95% for a standard normal distribution). The B-value result was negative, indicating that as age increases, the probability that the participant will be accurate declines. In particular, because the B-value for age is negative, the odds ratio value associated with it is less than 1.0 (Exp(B) = 0.967). Coefficients of interest are those that are above or below 1.0. When the Exp(B) is less than 1.0, 1 divided by the Exp(B) coefficient is easier to interpret (Pedhazur, 1997). In our sample for this intersection, 1 / 0.967 yields a value of 1.03. Interpreted, this means that for every 1-unit increase in age (i.e., one year), the odds of being inaccurate increase 3%. Note, however, that this 3% increase is based on an exponential function, which means that a 2-year increase in age does not equal a 6% increase in inaccuracy.

Similar to intersection 2, intersections 5, 9, 15, 21, 24, 29, 31, and 35 had significant χ^2 for age and time. After examining the Wald statistic for these intersections, only age reliably predicted accuracy (see Table 4.2). Intersection 5 was composed of a vehicle turning left, other vehicles past the intersection, green proceed signals, four signs indicating traffic flow direction, and a pedestrian that appeared and disappeared. The pedestrian was moderately obscured by the vehicle turning. The correct decision was to stop because the pedestrian had a walk signal. The results for intersection 5 showed that for every 1-unit increase in age, the odds of being inaccurate increased 3%. This may be because many older drivers failed to see the pedestrian, and without the pedestrian present, it was safe to make the left turn.

The change in intersection 9 was the appearance of a pedestrian crossing the road from the right on a pedestrian crosswalk. The intersection was controlled, but showed a green proceed signal. It was unobstructed by other traffic. There was also a vehicle in the same lane, but well past the intersection. The correct course of action was to stop for the pedestrian, although the light was green. The results for intersection 9 indicate that for every 1-unit increase in age, the odds of being inaccurate increase 4%. Older drivers unsuccessfully detected the pedestrian at this intersection. The size of the pedestrian may have contributed to older drivers failing to detect it ($\theta = 1.16° \times 2.24°$). Again, if the pedestrian was not detected, it was safe to cross this intersection.

Intersection 15 contained traffic lights, showing a green proceed signal, and a bus located to the right. Vehicles were present in the opposite flow of traffic, but were beyond the intersection. A no-turns sign on the overhanging light pole changed in this intersection. The correct decision was to adhere to the sign and not proceed with the left turn. For every one-unit increase in age, the odds of being inaccurate were 5%. The sign was a relatively small change ($\theta = 0.71° \times 0.71°$). Failing to detect the sign meant that many older drivers continued to proceed through an otherwise safe intersection.

Intersection 21 contained vehicles directly in front and to the right of the participant's viewpoint. The intersection was controlled and the lights were green. A truck was present on the one-way street onto which the participants were asked to turn left. The truck's location on the side street clearly indicated that the street was a one-way and that a left turn could not be made. Furthermore, the change in the intersection was a no left turn sign on the traffic light pole. The correct decision was to observe the no left turn sign and not proceed with the left turn. The odds ratio calculated for intersection 21 revealed a 15% increase in inaccuracy for a 1-unit increase in age.

Intersection 23 was located in downtown Calgary. The traffic lights were green, the one-way sign and no-turns sign were clearly visible on the light pole. The change inserted into the image was a van in the opposite flow of traffic, which appeared to be turning left in front of the participant's vehicle. The change was relatively large (visual angle = 2.23° x 1.97°). A commercial truck was also stopped on the opposite side of the road, next to where the van appeared and pedestrians also stopped on the opposite side of the road, next to where the van appeared and pedestrians were visible on the right-hand sidewalk, across the intersection. For every 1-unit increase in age, there was a 5% increase in the odds of being inaccurate. Older drivers saw the van, but were unsure of its intentions. The van was just over the double yellow line, and angled for a left turn. The correct decision was to not go, as the van was across the double line and in the participant's line of travel.

The pedestrian crossing lights in intersection 24 showed the crossing was potentially in use. There were stationary vehicles ahead of the participant's vehicle, of which only the car in front had its brake lights on. The change associated with this intersection involved the appearance of a pedestrian on the crosswalk in front of the stopped vehicles. The pedestrian was visible from the participant's viewpoint. A 1-unit increase in age increased the odds of being inaccurate 4%. The correct decision in this intersection was to stop; however, if the pedestrian were not detected, it would be safe to proceed.

Intersection 29 contained a turn lane with roadway markings, a stopped vehicle to the right, and a series of traffic flow signs that indicated lane designation. A pedestrian appeared on a crosswalk in front of a stopped car just to the right of the participant's viewpoint; only the top half of the pedestrian was visible beyond the car. A 1-unit increase in age increased the odds of being inaccurate 4%. The pedestrian's clothing blended somewhat with the background, and the luminance change between the background and the pedestrian was only -0.94 footlambert, meaning there was little luminance change. The lack of contrast between the pedestrian and the background may have obscured the change. Detection of the pedestrian was critical for making a correct decision to stop, as the intersection was otherwise clear. Older drivers who failed to see the pedestrian often chose to go.

In intersection 31, a yellow taxi was positioned just ahead of the field of view on the right hand side. The taxi was the change in this intersection and it was clearly over the stop line and into the intersection. The traffic lights for the participant were green and pedestrians were just finishing crossing the intersection toward the left side of the image. A vehicle was also stopped on the other side of the intersection in the opposing lane. The correct decision here was to stop because the taxi appeared to be violating the intersection. A 1-unit increase in age revealed a 3% increase in the odds of being inaccurate. The change was large (visual angle = 4.2° x 2.25°) but older drivers often missed it and chose to proceed. Others, who saw the taxi, may have assessed the likelihood of it violating the traffic signals to be relatively low and chose to proceed as well.

The change associated with intersection 35 was relatively small (visual angle = 0.49° x 1.50°). A pedestrian, jaywalking, appeared behind a minivan turning to clear the intersection. Only the top half of the pedestrian was visible beyond the van. The intersection lights were green, the left turn light was red and there was a line of vehicles stopped on the opposite side in the left turn lane. A 1-unit increase in age increased the odds of being inaccurate 7% for this intersection. A failure to detect the pedestrian led to incorrect decisions because if the pedestrian is not present the intersection is safe to cross. The correct decision was to stop and wait for the pedestrian to clear the intersection.

4.5.5 Intersection Decision Accuracy with Time as a Predictor

In intersection 13, the traffic lights changed from green to yellow. The intersection was congested, with vehicles in both lanes in front of the participant and in the opposing lanes. Intersection 13 showed only marginally significant results. Time was a significantly reliable predictor of accuracy; age, however, was not. The results indicate that the odds of being accurate were almost 4 times greater in the 8-second versus the 5-second presentation time. Participants in the 8-second condition had more time to assess the intersection and make a correct decision. In this case, the correct decision was to continue through the intersection because it was too late to stop. Stopping meant the participant's vehicle would potentially block the intersection. Participants who had a shorter amount of time to view the intersection may have chosen a socially desirable response to stop at the yellow light because they were incapable of fully assessing the nature of the intersection.

4.5.6 Intersection Decision Accuracy with Age and Time as Predictors

Both time and age reliably predicted accuracy in intersections 8, 12 and 27. In intersection 8, four vehicles were stopped in the left turn lane next to the participant, who was in a straight-ahead lane. Both traffic lights were green and there was one vehicle just before the intersection in the lane to the right of the participant. This vehicle was braking. The change incorporated in this intersection was a pedestrian running out in front of oncoming traffic, from behind the vehicles stopped in the left turn lane. The odds ratio for intersection 8 indicated that for every 1-unit increase in age, the odds of being inaccurate increased by 7%. Older drivers did not see the pedestrian. Attention was directed toward the line of vehicles stopped on the left and the state of the lights. As with other intersections, detecting the pedestrian was critical for making the correct decision to stop. Time was also a significant predictor at this intersection. The odds of being accurate were 5 times greater for the 8-second category than the 5-second category. The longer viewing time may have facilitated the detection of the pedestrian.

Intersection 12 was a one-way street and the lights were green. There was a cyclist on the left, with his foot down on the road indicating he was stopped. The intersection was sunny, but shadowed on either side of the intersection. A pedestrian, exiting from a vehicle into the street next to the participant's lane, appeared on the other side of the intersection in the shadows. The pedestrian was small (visual angle = 0.26° x 1.08°). For this intersection, a 1-unit increase in age increased the odds of being inaccurate by 9%. Time was positively related and indicated that the odds of being accurate were almost 7 times greater for the 8-second condition than the 5-second condition.

Intersection 27 did not contain any manipulated changes. The intersection was congested, with vehicles in all three lanes in front of the participant. The traffic lights were green. There was a moving van in the lane directly in front of the participant, next to the pole containing a one-way sign pointing left. There were also trees and buildings on both sides of the street. For every 1-unit increase in age, the odds of being inaccurate increased by 3%. Drivers were asked to decide whether it was safe to turn right at this intersection. The correct decision was to not make the right turn because of the one-way sign. Older drivers often failed to see the one-way sign and decided it was safe to turn right. The odds of being accurate were almost 6 times greater for the 8-second condition than the 5-second condition. More time allowed participants to better scan the scene before making a decision.

4.5.6.1 Decision Accuracy by Age Group

Analysis of age group accuracy differences for the 14 significant intersections was performed using an analysis of variance (ANOVA). A significant difference was found for correct accuracy between each age group, *F*(3,52)= 11.42, *p*= 0.0001. Four follow up t-tests were conducted using a Bonferroni correction at α = 0.0125 (*i.e.*, 0.05/4) to control for the error rate. The youngest age group (*i.e.*, 18-25) had significantly higher accuracy scores (*M*=17.05, SD=5.50) on the 14 intersections than the young-old (*i.e.*, 65-73) age group (*M*=9.22, SD=7.76), *t*(26)= 3.08, *p*= 0.005 and the old-old (*i.e.*, 74+) age group (*M*=6.10, SD=6.01), *t*(26)= 5.01, *p*= 0.0001. The middle age group (*i.e.*, 26-64) had significantly higher accuracy scores (*M*=17.28, SD=5.38) on the 14 intersections than the young-old age group, *t*(26)= 3.19, *p*= 0.004 and the old-old age group, *t*(26)= 5.18, *p*= 0.0001. Overall accuracy percentages calculated for the 14 significant intersections are shown in Figure 4.2.

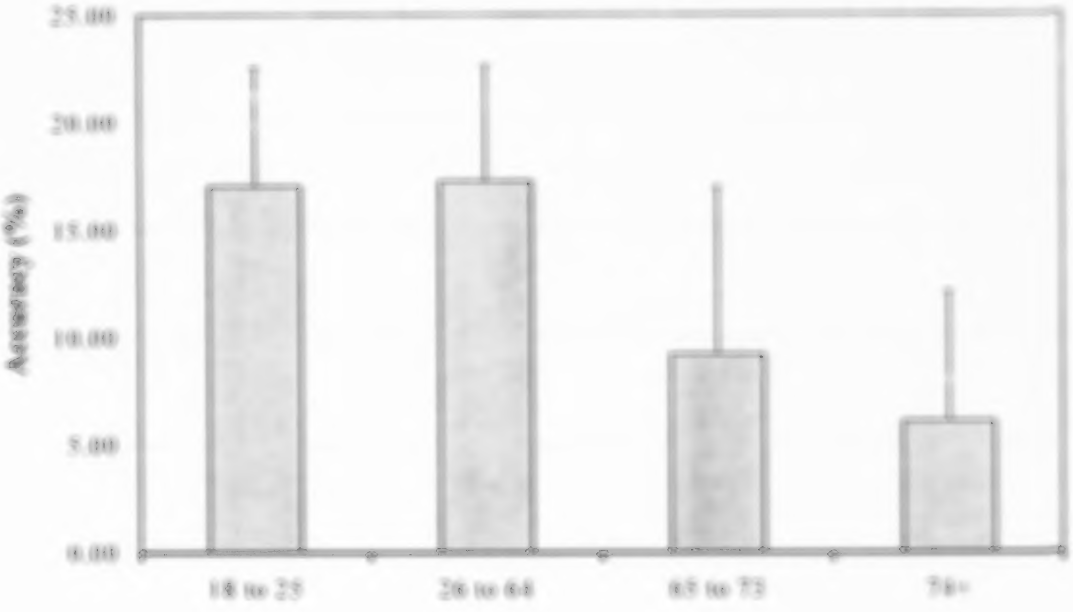


Figure 4.2 Overall decision accuracy (%) by age group for the 14 significant intersections. Error bars indicate 1 standard deviation (SD).

4.6 Qualitative Analysis

4.6.1 Qualitative Methods

The second question participants were asked after each trial was to rank order the elements in the intersection scene (e.g., pedestrians, cars, etc.) that influenced their decision to go or not to go in order of importance (most important to least). The experimenter recorded the verbal responses and participants were reminded to do the ranking of elements as they gave their answer. One experimenter coded the information for all 36 trials per participant and a second experimenter checked the data as a form of interrater reliability. The two experimenters had a 90% rate of agreement as to how to classify the responses. When discrepancies arose, a third experimenter was consulted to resolve the classification. The responses were divided into two frequency tables for younger participants (18-64, N = 32) and older participants (65+, N = 28). Only the top three responses for each trial across younger and older participants were recorded in the frequency tables. The qualitative analysis only focused on the 18 intersections that showed significant time or age effects with an interest in further explaining those differences (effects).

4.6.2 Qualitative Results

Intersection 2 depicted a yellow light, with no other vehicles driving on the roadway. Two pedestrians were standing on the far right curb. The photograph was taken after the vehicle entered the intersection; therefore, the correct decision was to continue through the intersection on the yellow light. This intersection showed a significant age effect using logistic regression (LR), and that finding was qualified by the pattern of participant responses. The majority of younger (N = 27) and older (N = 26) participants indicated that the yellow light was most influential in their decision making. However, the younger participants usually indicated that they realized their vehicle had already entered the intersection and chose to proceed (go decision) on the yellow light. In contrast, the majority of older participants chose to stop (no-go decision) and made no indication that they realized they were already in the intersection. Overall, the younger participants correctly evaluated both the location of the vehicle in the intersection and the nature of the yellow light, and indicated this in their responses. The older participants appear to have chosen to respond to the yellow light without considering where the vehicle was located in the intersection.

Intersection 7 depicted a green light on a one-way street. There were two vehicles to the right that had already proceeded through the intersection. The vehicle ahead and to the left was making a left turn. A pedestrian was standing on the left corner of the intersection but was not attempting to cross the street. The correct decision was to not make the left turn. This intersection showed a significant age effect using LR. Younger (N = 15) and older (N = 17) participants indicated that the green light was the most influential element in their decision. Younger participants (N = 10) stated that the pedestrian on the corner was influential in their decision and they stopped to let the pedestrian cross. In contrast, older participants (N = 9) did not list the pedestrian as frequently as the younger participants, often because they did not see the pedestrian.

Intersection 8 depicted a red light with a clear lane ahead. However, there were vehicles lined up to the left with a pedestrian running out from between two vehicles. The pedestrian was the relevant change in this intersection. The correct decision was to stop as the pedestrian was in the intersection. This intersection showed a significant age effect using LR, which was qualified by the pattern of participant responses. Younger participants (N = 19) indicated that the pedestrian was influential in their decision not to go while older participants did not notice or mention the pedestrian at all. The primary responses of the older participants were the green light (N = 26) and clear intersection (N = 15).

Intersection 9 depicted a green light with the vehicle approaching a crosswalk. A pedestrian was stepping out from the right curb into the crosswalk against the red light. The pedestrian was the relevant change in the intersection. The correct decision was to stop because the pedestrian was partially in the lane of travel. This intersection showed a significant age effect using LR. Younger participants (N=20) indicated that the pedestrian was most influential in their decision while older participants (N=13) stated that the green light was most influential. Furthermore, older participants (N=7) also stated that the intersection was clear. Fifteen older participants mentioned the pedestrian, often after mentioning the green light or the clear intersection.

Intersection 12 depicted a green light on a one-way street with a clear intersection ahead. There was a cyclist stopped on the left. After the intersection, a pedestrian was about to walk onto the street into the participant's lane. The pedestrian was the relevant change in this intersection. The correct decision was to stop because the pedestrian was in the way. The intersection showed a significant age and time effect using LR. Younger participants (N = 19) and older participants (N = 28) indicated that the green light was most influential in their decision. No older participants noticed the pedestrian, whereas a total of 17 younger participants noticed the pedestrian. Older participants more often assumed that the cyclist was going to move through the intersection, although the cyclist's foot was on the ground. No younger participants made this assumption.

Intersection 17 depicted a green light changing to a yellow light on a two-way street. The vehicles directly ahead had already cleared the intersection. There were oncoming vehicles in the left turn lane. The close proximity to the intersection indicated that the correct decision was to proceed straight through the intersection on the yellow light because it appeared there was not enough room to stop. This intersection showed a significant time effect using LR. Younger participants (N = 10) and older participants (N = 21) indicated that the changing lights were most influential in their decision.

Intersection 19 depicted a green light on a two-way street with a no turns sign on the light standard. The no turns sign was the relevant change in this intersection. The intersection showed an oncoming vehicle and a bus to the right. This intersection showed a significant age effect using LR, and that finding was qualified by the pattern of participant responses. A total of 17 younger participants noticed the no turns sign and chose not to make the left turn. Only 5 older participants indicated that the no turns sign was influential in their decision. Older participants focused mostly on the oncoming vehicle (N = 12) as well as the green light (N = 9). Younger participants also stated the green light (N = 8) and oncoming vehicle (N = 8) as other common responses.

Intersection 21 depicted a green light on a one-way street. The relevant change was a no left turn sign on the light standard. There were two vehicles directly ahead about to enter the intersection. The participant was instructed to turn left if it was okay to do so. However, a left turn at this intersection would put them headed the wrong way on a one-way street. The correct decision was to not make the left turn and to proceed straight instead. This intersection showed a significant age effect using LR. That finding was supported by the self-report. Younger participants (N = 20) indicated that the no left turn sign was most influential in their decision compared to older participants (N = 8). Younger participants gave secondary responses such as being unable to turn onto a one-way street (N = 11), not being in the correct lane to negotiate the turn (N = 7), or traffic impeding the turn (N = 7). Older participants (N = 10) used the green light to make their decision while younger participants did not, and often completely failed to see the no left turn sign.

Intersection 23 depicted a green light on a two-way street. There was an oncoming van midway in the intersection about to make a left turn. This van was the relevant change in this intersection. The correct decision was to stop and not proceed straight because the van was making a left turn in front of the participant and had already crossed the double yellow line. This intersection showed a significant age effect using LR. Younger participants (N = 18) and older participants (N = 12) stated that the oncoming van turning left was most influential in their decision. However, more younger participants (N = 20) actually saw the van compared to older participants (N = 15). Despite an oncoming vehicle in the way, both younger (N = 16) and older (N = 9) participants used the green light when making their decision.

Intersection 24 depicted a one-way street with vehicles stopped ahead. There were flashing yellow lights to indicate that a pedestrian was crossing at the crosswalk. The pedestrian was the relevant change in this intersection and the correct decision was to stop. This intersection showed a significant time and age effect using LR. The main response for younger participants (N = 13) was the pedestrian while older participants (N = 11) mainly noted the yellow pedestrian lights. More younger participants (N = 23) than older participants (N = 10) noticed the pedestrian. In total, both younger participants (N = 19) and older participants (N = 7) also used the presence of vehicles ahead to help make their decision.

Intersection 27 depicted a green light on a one-way street. There was a one-way sign pointing left on the light post across the intersection, indicating a one-way street to the left. Vehicles were in all three lanes ahead of the participant. The correct decision was to not make the right turn because of the one-way sign. A significant age effect was found with LR. Both younger participants (N = 21) and older participants (N = 11) indicated that the one-way street sign most influenced their decision. However, both younger and older drivers also made responses that were not indicative of correct decisions. Other main responses for younger participants included the green light (N = 12), no pedestrians (N = 6), and a clear intersection (N = 6). Older participants also included the green light (N = 11), no pedestrians (N = 4), and a clear intersection (N = 4) in their responses. Overall, more younger participants saw the one-way sign and made the correct decision to not proceed. However, participants in both age groups who did not notice the sign were likely to say they would proceed based on the other elements in the scene.

Intersection 29 depicted a green light with the vehicle approaching the intersection in the left turn lane. A vehicle on the right was stopped ahead at the stop line with a pedestrian in front. The pedestrian was the relevant change in this intersection, and the correct decision was to stop. The intersection showed a significant age effect using LR. Both younger (N = 13) and older (N = 13) participants indicated that the green light most influenced their decision to proceed with the left turn. Ten younger participants and two older participants saw the pedestrian and indicated that the pedestrian was most important for their decision. The second most common responses for both age groups included being in the correct lane to proceed (younger = 8, older = 15) and the intersection being clear (younger = 7, older = 4). Overall, because they were more likely to see the pedestrian, a higher number of younger participants made the correct decision to stop when compared to older participants.

Intersection 31 depicted a green light on a two-way street. There was one oncoming vehicle stopped ahead waiting for pedestrians to cross. The pedestrians were not in the way for the participant. A taxi entered the intersection on the red light from the right side. The taxi was the relevant change in this intersection. The correct decision was to stop to avoid the taxi. This intersection showed a significant age effect using LR, which was qualified by the pattern of participant responses. Overall, 18 participants noted the taxi as either most important or second most important in their decision. In contrast, older participants (N=12) mostly noted the green light, with only 3 noting the taxi at all. Overall, older participants did not notice the taxi entering the intersection and were willing to proceed through the intersection based on other elements (e.g., green light) in the intersection.

Intersection 35 depicted a two-way street in which vehicles proceeding straight had a green light and vehicles turning left had a red light. There were oncoming vehicles stopped in the left turn lane. There was a van completing a left turn through the intersection, just to the right of the participant's viewpoint. A pedestrian, crossing against the red light, was partially visible behind the van. The relevant change in this intersection was the pedestrian and the correct decision was not to proceed because of the pedestrian illegally crossing the street. This intersection showed a significant age effect using LR; however, this finding did not seem to be qualified by the pattern of participant responses. The majority of younger (N = 27) and older (N = 22) participants indicated that the green light was most influential in their decision making. Younger participants (N = 31) also based their decision on the clear intersection while older participants (N = 14) also based their decision on the van clearing the intersection. Several younger participants detected the pedestrian; however, they chose to continue on the green light and assumed the pedestrian would not continue to cross.

4.7 Discussion

This study used a modified flicker paradigm to assess the effects of decision accuracy at intersections under imposed time constraints. We expected that both older and younger drivers would have difficulties identifying hazards at visually complex intersections, but that older drivers would perform less accurately because of age-related declines in attentional scanning and working memory capacity. In particular, the effect of time on the capability to make accurate intersection decisions was a central focus.

Participants in the youngest age group (18-25) self-reported the most traffic accidents in the last five years and had the greatest number of violations (see Table 4.1). The youngest age group also had the second highest decision accuracy across the 14 significant intersections (see Table 4.3). Reasons for more accidents and violations can be attributed to risk-taking behaviour and inexperience (Deery & Fildes, 1999; Nell, 2002). Higher decision accuracy by younger drivers may be due, in part, to age differences in scanning abilities and working memory capacities (Scialfa et al. 1994).

Both age and time were significant predictors of intersection decision accuracy in 14 of the 36 intersections tested. Age as a predictor of accurate decisions was significant in 13 of these 14 intersections. Out of these 13, 10 intersections had age-only effects and 3 had time and age effects on accuracy predictions. Out of the 10 intersections with age as a significant predictor, 7 intersections had pedestrians as the critical change element. In 6 of those 7 intersections, the correct decision was not to proceed, because the decision to go would have resulted in striking the pedestrian. However, if a participant failed to see a pedestrian, the intersection was safe to clear, making detection vital for a correct decision. The pedestrians that older participants were more likely not to detect were those partially obscured by vehicles and other scene elements. Pedestrians not detected by older participants were relatively small in size and low in contrast from the background scene. Consequently, the pedestrians were more difficult to segregate from other objects.

Older participants were also more likely to miss relevant vehicles. In intersections 23 and 31 (see Appendix M), both vehicles were relatively large and conspicuous (visual angles = 2.23° x 1.97° and 4.2° x 2.25°, respectively). Intersection 23 had a minivan in the opposing lane of traffic and intersection 31 had a yellow taxicab to the right of the participant's vehicle that changed in the scene. The luminance change of the taxi appearing and disappearing was 57.1%. With the taxi present, the perceived brightness was greater than when the vehicle was absent. The vehicle in each intersection intentionally violated established traffic laws. Older participants may have had lower expectations concerning the actions of those vehicles. When visually reconstructing the scene, from one flicker to the next, attention was possibly focused on what they expected to encounter, such as lights and signs (Theeuwes, 1996), as opposed to vehicles violating the traffic code.

Traffic sign changes were more likely to be missed with age (Ho et al., 2001). Although the sign changes were relatively small, with visual angles of 0.71° x 0.71° and 1.06°x 1.06°, respectively, for intersections 15 and 21, they were critical to safe intersection decisions. In intersection 21, a vehicle travelling in the correct direction on a one-way street provided redundant information that the no left turn sign also conveyed. Older drivers appeared to overlook both forms of information provided and made incorrect decisions.

Time as a predictor of accuracy was significant for four of the intersections. Accuracy was five to eight times greater for the 8-second condition than the 5-second condition in these intersections. Three of those intersections (8, 12, 27) also had age factors. Intersections 8 and 12 had pedestrians as the changing element. Pedestrian size may have limited detection by older participants, more so when given 5 seconds to make a decision. Older participants may have scanned a few expected locations for information in the available time. In a limited viewing time, older drivers are likely to execute fewer eye movements (Ho et al., 2001), and once objects are fixated, more time is required to process information (Scialfa, 1997). Younger drivers, in the same time constraints, are likely to make more eye movements and fixate for shorter periods of time. Thus, older drivers are less likely to scan and process as many objects in the traffic scene.

If older drivers are adopting a scan strategy that favours traffic lights or proximal vehicles, locations where hazards unexpectedly appear are less likely to be seen and incorporated into decisions. The modified flicker method makes the search for relevant objects effortful. A total of 7 of the 14 significant intersections had pedestrians as the changing element. Pedestrians in the intersections were more difficult for the older participants to detect as they appeared in unexpected locations.

The qualitative analysis supports the quantitative results by showing which information is relevant for older and younger drivers to make decisions. For a large portion of the results, both older and younger drivers fixate on the state of the traffic light, if one is present at the intersection. However, younger drivers appear to scan the images faster, in all cases, to extract other potential hazards. In most instances, older drivers fixated on traffic lights and occasionally additional signage, whereas younger drivers, through shorter fixations, were able to identify other hazards in addition to the light information. The qualitative results further outline missed hazards by older drivers. Focusing on signs and lights alone to help navigate complex intersections, older drivers seemed confident to make a decision, often not seeing or realizing the appearance of a pedestrian. Moreover, if a sign was relevant to a correct decision, younger drivers were able to integrate the sign information faster. Older drivers appeared to fixate, from flicker to flicker, just on expected objects (i.e., lights and signs) in the intersection.

Twenty-two of the intersections that participants judged did not yield age or time as significant predictors. Thus, intersection decision performance was not appreciably different across age for two thirds of the intersections tested. This result suggests that older drivers are able to make effective decisions in many circumstances. However, when exceptional events occur, such as the sudden appearance of a pedestrian, detection may suffer. Similarly, where many potential hazards co-occur, the capability to scan all objects in a limited time may also hinder detection. Complex intersections containing multiple signs, traffic control devices, and increased traffic congestion are examples of multiple objects. In time-critical situations, such as approaching a complex intersection, older drivers may not have sufficient attentional resources to cope with all intersection elements. Dropping elements from working memory, due to complexity, also has the potential to cause critical decision errors. Despite this, drivers of all ages successfully navigate complex intersections on a daily basis.

4.7.1 MFM as a Screening Test

The modified flicker method (MFM) shows promise as a means to screen drivers who may have difficulties. It appears that change blindness, in this instance, does reduce identification of critical hazards, as illustrated by pedestrian and vehicle detection in this study. Also, the results suggest that aging drivers fail to detect hazards more often than younger drivers at complex intersections. If the 14 significant intersections were collapsed into a screening test, it could be further tested for validity and reliability. The total time to take the test, including the practice, would be about 10 minutes. One of the weaknesses of the useful field of view (UFOV) test is the length of time required to take it. Another weakness is the lack of face validity. Both of these limitations could be overcome by the MFM. Generally, the MFM offers a means to screen all drivers, to determine their capability to scan for hazards within a driving scene. Adopting a similar test measure at provincial or state motor vehicle departments, once a potentially dangerous driver has been identified, may provide specific diagnostic capability.

Aging drivers, in particular, are susceptible to missing important items at intersections. It appears that older drivers have adopted particular strategies of coping with complex intersections. By focusing on specific items such as traffic, traffic control devices, and the roadway ahead, older drivers have adapted a means of identifying the most relevant items immediately. Unfortunately, concentration on these elements alone means the potential to miss unexpected hazards. Training for older drivers, to emphasize aging limitations, can help adapt them to the complexity of intersections and hazards, such as pedestrians.

In terms of roadway design, adding signs, lanes, and traffic lights to an intersection may alleviate traffic woes in the short term, but probably increase the likelihood of driver error. The MFM could also be used to assess the limits of intersection complexity on driver turn performance. For example, more signage and traffic lights may lead to more accidents due to an increase in complexity beyond the number of objects that can be scanned for by older drivers making turn decisions. Time and age implications, as demonstrated in the present study, should be further assessed in future research to determine appropriate designs.

4.7.2 Simulator Blindness

Results of the change blindness study demonstrated specific limitations of drivers in detecting objects in complex intersections, and guided the development of the driving simulation study. To bridge the gap from static images to the dynamic traffic environment, both static and dynamic flicker methods were used in the follow-up driving simulation study, which is reported next. The construction of the simulated environment involved mapping the characteristics of the static images of intersections into the interactive driving scenarios of the simulator. Specifically, complex intersections that had objects such as pedestrians, signs, and proximal vehicles were programmed into critical experimental events in the simulated environment. Further, the modified flicker method previously employed was used in addition to driving in the simulated traffic environments, but the number of static images was reduced from 36 to 12.

We expected that the alternating performance of drivers in the simulated traffic environment would be better than when viewing static images. When critical objects such as vehicles and pedestrians undergo motion, they are easier to detect. However, static objects such as signs and signals, because they do not move *per se*, would be detected at the same level of performance as the static modified flicker method images. As before, limited time to detect, decide, and act was expected to adversely affect older drivers more than younger drivers.

5. DRIVING SIMULATION STUDY

5.1. Introduction

The purpose of the driving simulation study was to replicate and extend the findings of the change blindness study in the dynamic driving conditions provided by the simulator. Data from the change blindness study was analyzed and a subset of 12 intersections was chosen for this study. In the change blindness study, these intersections elicited either performance differences between older and younger drivers, where younger drivers performed better on average than older drivers, or decrements in both age groups. The data collected in the change blindness study was also used to design four experimental simulator scenarios for participants to travel. The goal was to reproduce intersection problems as evidenced by the change blindness study. Scenarios developed included events such as a last-minute yellow light and a vehicle violating a stop light. One scenario incorporated an 80 ms inter-stimulus interval (ISI) that appeared while participants were navigating a left turn. The interval resembled the grey screen used in the change blindness study. It was hoped that performance on the simulation tasks would correlate with the performance on the change blindness task. Participants completed both a change blindness task and a driving simulation task in this study, with half the participants completing the change blindness task first and half completing the simulation task first.

5.2. Driving Simulator

5.2.1. Hardware

The University of Calgary Driving Simulator (UCDS), at the time of this study, was the most advanced driving simulator in Canada. Integrated by KQ Corporation, the UCDS is composed of five networked 1 GHz SGI workstations. A NetGear FS108 Fast Ethernet switch handles the network communication between visual channels, authoring workstation, and the host computer. Three workstations with nVidia Gforce3 graphics cards are linked to three projectors. One workstation manages I/O, graphics, and audio. The fifth workstation is a development platform for traffic scenarios and experimental management. Three Epson 703C projectors display (1064 x 768 resolution and maximum lumens 1000) onto three WrapAround Clarion Screens by Draper, each of which measures 2.2 m wide by 1.65 m high. The display refresh rate of the system is

60 Hz. The total projected forward field of view is 150 degrees. A Saturn SL1 is situated in front of the screens (see Figure 5.1). The brake, accelerator, and steering are interfaced to the graphics by way of an A/D computer under the hood of the Saturn at 400 Hz. The steering wheel "stiffness" is controlled as a function of speed by a torque motor (Model No. SE 808). Brake and accelerator inputs are modelled in software to result in appropriate deceleration and speeds. The speedometer (km/h), interior lights (i.e., dashboard, radio, and center console), and fan provide speed, display information, and air, respectively. Road noise is presented through a Monsoon MM2000 stereo system with a base and surround speakers. Noise scales with the speed of the vehicle. Additional sounds can be attached to a range of events in the traffic environment.

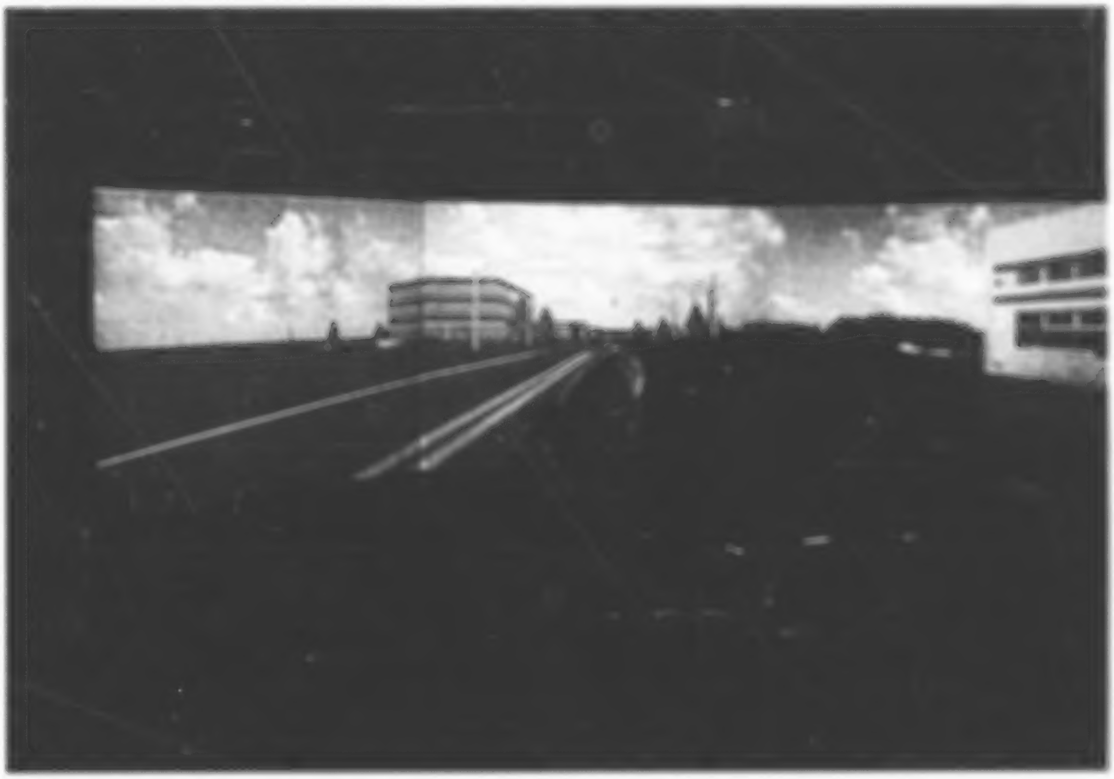


Figure 5.1. University of Calgary Driving Simulator (UCDS). Shown with projectors, screens, and Saturn SL-1.

Within the simulator, video and audio systems are used for participant monitoring, communication and to record participant and experimenter activities. A system of three black and white "lipstick" cameras (Model No. KPC 500) are mounted inside the Saturn and provide views of the driver's face, hands on the steering wheel, and feet on the brake and accelerator. A fourth colour camera (Panasonic Model No. WV-CP460 with a WVLA 9C3A 9 mm Panasonic lens) shows the centre screen of the simulated traffic environment. All four views are displayed using a multiplexer (Panasonic Quadsystem WJMS 424) on a 23" Toshiba monitor (see Figure 5.2). Real-time data from the steering wheel, brake, and accelerator are overlaid on corresponding video images using a BOB-II Video Text Overlay Module. Data streams indicate deflection angle of the steering wheel and the percent depression of the accelerator. A microphone is inserted in the driver's side visor that can pick up the verbalizations of participants. A separate speaker (Yamaha Monitor Speaker 101) directly behind the driver can present verbal directions from the experimenter to the participant through a table-top microphone (Shure BG3.1) at the central workstation. An audio mixer (Behringer Eurorack MX802A) handles all audio to and from the vehicle and experimenter workstation. A VHS player (JVC Super VHS ET) records the multiplexed views of the driver, the forward field of view, and audio to tape.

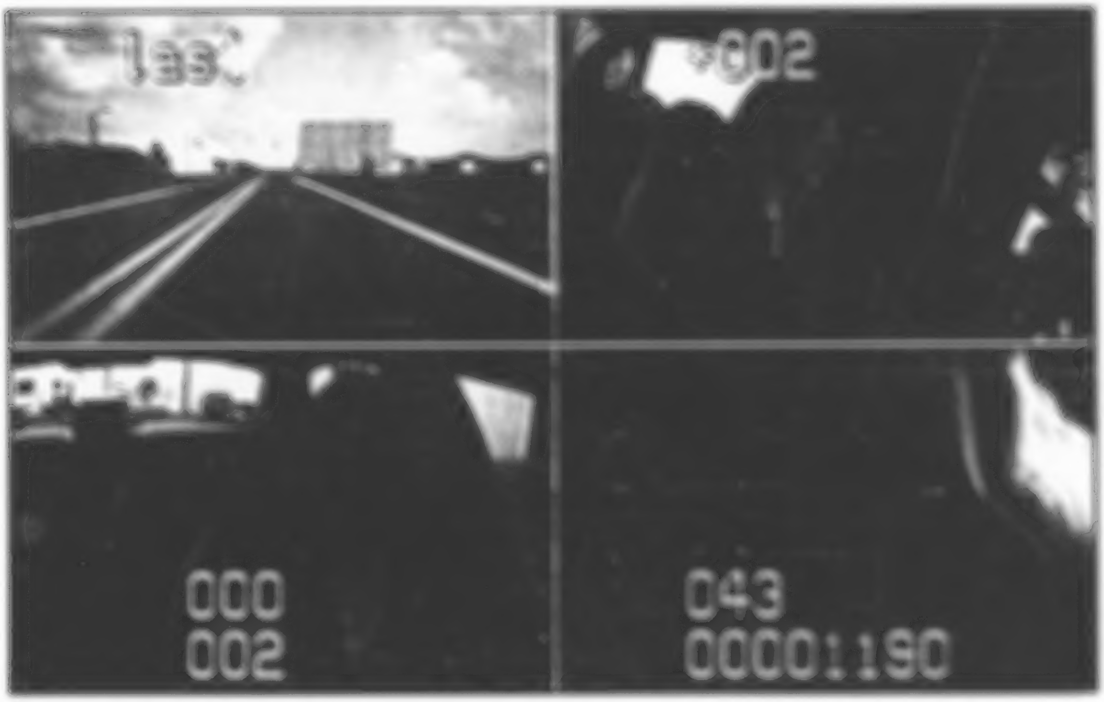


Figure 5.2. Recorded camera views: forward field of view in the simulator (top left); steering wheel hand positions (top right); face and eyes of driver (bottom left); and feet, accelerator, and brake (bottom right).

5.2.2 Simulation Software

HyperDrive (v. 1.4.0) provides the means to develop traffic environments and experimental scenarios for the driving simulator. The *tile* is a basic unit of a traffic environment. Tiles can be selected from an extensive pallet of intersections, freeway sections, streets, and so forth, all of which adhere to the *Manual on Uniform Traffic Control Devices* (MUTCD). Modifications to the speed limit signs were adapted for kilometres per hour by KQ. Once a tile is selected it can be placed into an environment and linked with other tiles to compose a traffic environment. Scenarios are specific situations that can be built to record driver behaviours in a specific traffic environment of interest. For example, an intersection can be built that will test the perception-response time of a driver to the change of a light or the incursion of another vehicle that runs the lights. Dependent variables that can be collected include a range of timing variables such as perception response time (PRT), velocity, lane position, steering deflection angles, acceleration percentage (of accelerator), deceleration percentage (of brake), heading, X-Y coordinates, lateral acceleration, longitudinal acceleration, collision detection, and a variety of derived variables. The density of the ambient traffic is controlled with a windows slider such that low, medium, and high traffic flows can be introduced. Alternatively, specific flows can be established using Tcl scripting. Fog can be introduced in a similar fashion using a slider control for distance.

5.2.3 Scenario Development

In addition to the creation of simulated graphic environments in which to drive, the behaviour of other vehicles, the timing of lights, ambient traffic, pedestrian behaviours, and sign placement can be manipulated. Scenarios for driving simulation training and experimentation were developed in accord with the research objectives of the study.

5.3. Participants

Older (65 to 80) and younger (18 to 25) drivers were recruited for this study. The recruiting methods for this study were the same as those used in the change blindness study (see section 4.2). Older drivers were recruited from local senior centres and younger drivers from within the University of Calgary. A valid driver's licence and an active driving record were required for participation. Participants were screened, prior to entry into the study, for visual and cognitive disease, certain medication uses, acuity and contrast sensitivity, and the potential for simulator sickness. Compensation was $15 for seniors (or donation) and extra credit toward psychology course marks.

5.4. Change Blindness Experiment Procedure

The verbal instructions for the change blindness task were identical to those used in the change blindness study. However, in this experiment, participants remained in the driver's seat of the simulator and viewed the intersections on the forward screen. The images were projected from an Epson 703C projector mounted 6.2 m from the screen versus 3 m in the change blindness study. The participants viewed the images from a distance of 220 cm versus 300 cm in the change blindness study. Older (65+) and younger participants (18-25) viewed and responded to 12 intersections selected from the 36 used in the change blindness study. The 12 intersections for the experimental trials were chosen based on participant performance in the previous study. Appendix N contains a description of the 12 intersections. There were also three practice trials to familiarize participants with the task. The practice trials included a left turn, a right turn, and a straight-ahead situation. One practice trial also included an object change. The questions asked after the presentation of each intersection were identical to those asked in the change blindness study. There were two orders of the 12 intersections and the times for each intersection were counterbalanced as in the previous study (i.e., an intersection presented for 5 seconds in Order 1 was presented for 8 seconds in Order 2).

5.5. Simulator Experiment Procedure

In the simulator experiment, participants navigated a training roadway section with three parts and an experimental section with four parts. Instructions to turn or drive the posted speed limit were presented on the forward screen directly in front of the driver in white letters. The participant was also able to ask for clarification or help through the simulator's communication system.

5.5.1 Training Scenarios

The purpose of the training session was to familiarize participants with the steering, braking, and acceleration of the Saturn. The posted speed throughout the training run was 70 km/h. The first section required participants to drive straight for 1 kilometre. At the end of this section, participants encountered a stop sign-controlled intersection. Participants were encouraged to determine what an appropriate stop distance from the stop line was by receiving feedback from the experimenter. After the intersection, the participant was presented with a "prepare to change locations" message on the forward screen, followed a few seconds later by a "changing locations" message. At that point, the screens turned black and the simulator's operation was temporarily suspended while the new location loaded. After 5 seconds, the new location appeared, the simulator came back online and participants continued through the next scenario. The purpose of switching from one location to another rather than following a continuous route was to reduce the total simulation time (also see Caird et al., 2005).

In the second section, participants drove on a suburban section of roadway with parked, oncoming, and lead vehicles present. Oncoming ambient traffic was generated at intervals of 2 through 10 seconds between vehicles and also travelled 70 km/h. Participants followed a lead vehicle (SUV) through this scenario for 1.6 km then made a left turn at the first intersection. They then travelled another half kilometre, after which they were asked to make a right turn. Both turns were made at traffic light-controlled intersections. Participants were moved to the third practice scenario after the right turn. In the final section, participants drove straight again on a suburban road for approximately 1.5 minutes at 70 km/h. At the end of the segment, a green traffic light was triggered to turn yellow when participants were 3.00 seconds from the intersection. This yellow was used to gather baseline response times. At 70 km/h, the total time to complete the training run was between 5 and 6 minutes.

5.5.2 Experimental Scenarios

Each section consisted of a series of intersections where a critical event occurred at one intersection in the series. The locations of the critical events changed in each series, from occurring on the first intersection to occurring on the last, to prevent participants from anticipating an event. The length (in km) of each series of intersections also varied across the four series. Two experimental orders for the four series were created, with the first and last series fixed. Participants were instructed to drive 70 km/h in all scenarios and to otherwise drive as they normally would. Participants were moved between the four scenarios the same as in the practice section. Total driving time in the experimental session was between 10 and 15 minutes, depending on whether a break was taken.

In the first experimental series, which was presented first in both experimental orders, the principal event occurred at the end of the series when participants were asked to turn right at a set of traffic lights. Participants drove straight through two intersections (one stop light, one stop sign) before making a right turn. Oncoming traffic passed the participants at several points during the scenario (spaced 2 to 8 seconds apart), including three vehicles spaced 2 seconds apart at the approach to the intersection. The principal intersection was 875 m from the start. During the turn, a pedestrian appeared from the right where he was partially hidden by a pole and began to cross the road (see Figure 5.1). Participants drove into a long curve and the first set of intersections ended.

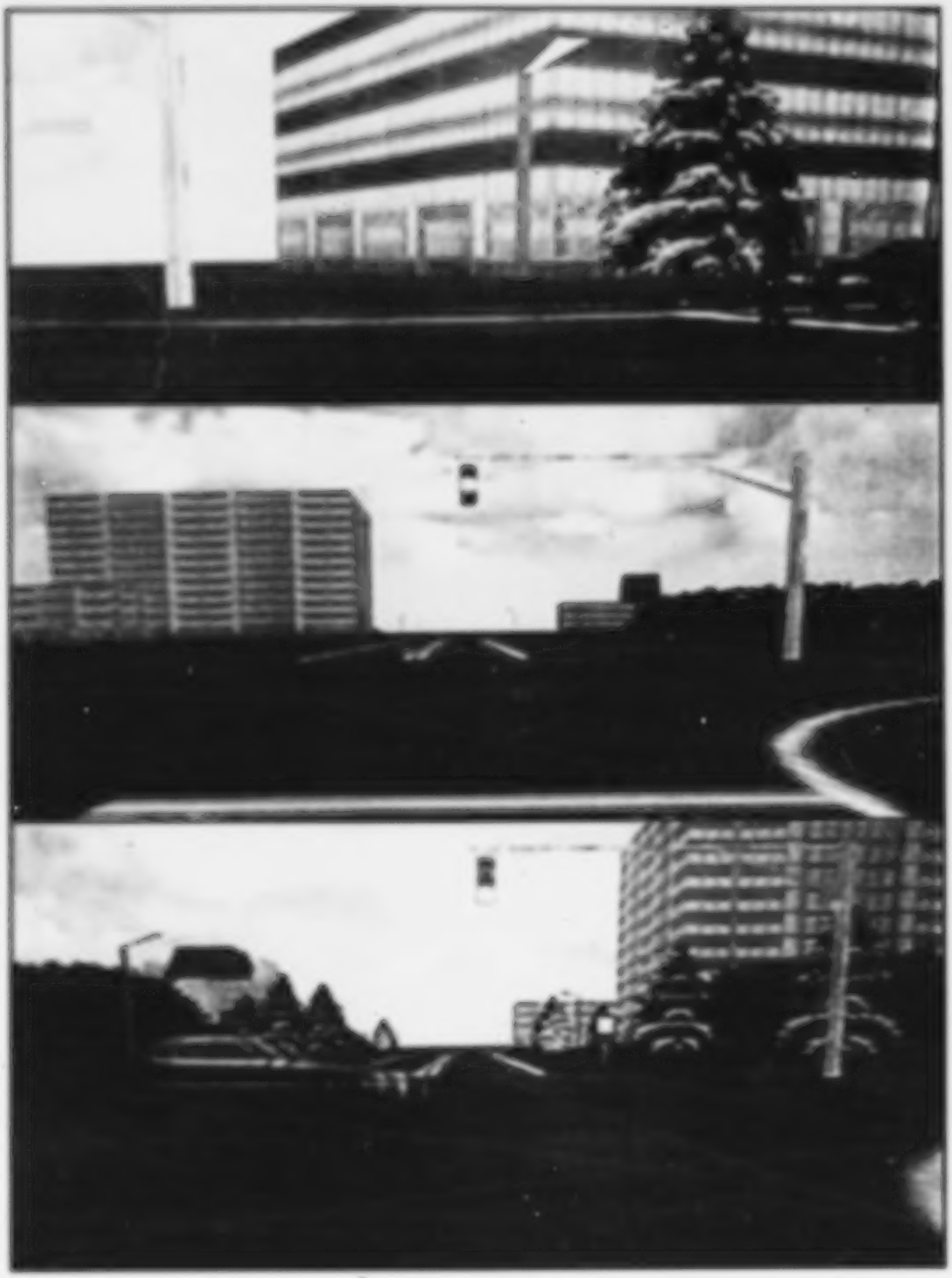


Figure 5.3 Critical experimental intersection events: pedestrian enters the street from behind a pole (top); last second light change from green to yellow (middle); and a vehicle runs red light from left (bottom).

In the second series, which was presented second in Order 1 and third in Order 2, the critical event occurred at the end, after the participants passed four intersections. En route to the principal intersection, participants first made a left turn at a set of lights, then proceeded straight through a second set of lights, a T-junction with stop sign, and a third set of lights. Total driving time from the start to the principal intersection was about 1 minute 30 seconds. Oncoming traffic was spaced between 2 and 8 seconds apart. The principal event in this scenario was a change from a green to a yellow light, which changed when participants were 2.5 seconds from the intersection. In this scenario, pedestrians walked back and forth in front of a shopping mall on the right-hand side of the participant just before the principal intersection. Vehicles also approached the intersection from the left and right as participants moved toward the intersection. The design of the intersection was intended to imitate complex scenes as used in the change blindness scenario (see Figure 5.1).

In the third series, which was presented third in Order 1 and second in Order 2, the principal event was a dynamic version of change blindness. Drivers followed a car from the beginning of the scenario for 282 m and were required to stop behind the car at a red light at the first intersection. Six vehicles, three from the left and three from the right, navigated the intersection from the perpendicular direction while the light was red. When the light changed, participants had to make a left turn while following the lead vehicle. When the participant's speed exceeded 12 km/h in the turn, all three screens flashed grey for 80 ms, in an identical manner to the static change blindness situation. The presentation of the grey screens masked the appearance of a pedestrian crossing the road from the right, just behind the lead vehicle and just in front of the participant's vehicle (see Figure 5.2). Once the left turn was completed, the driver continued straight for another 179 m and passed a stop sign-controlled intersection before moving to the next scenario.

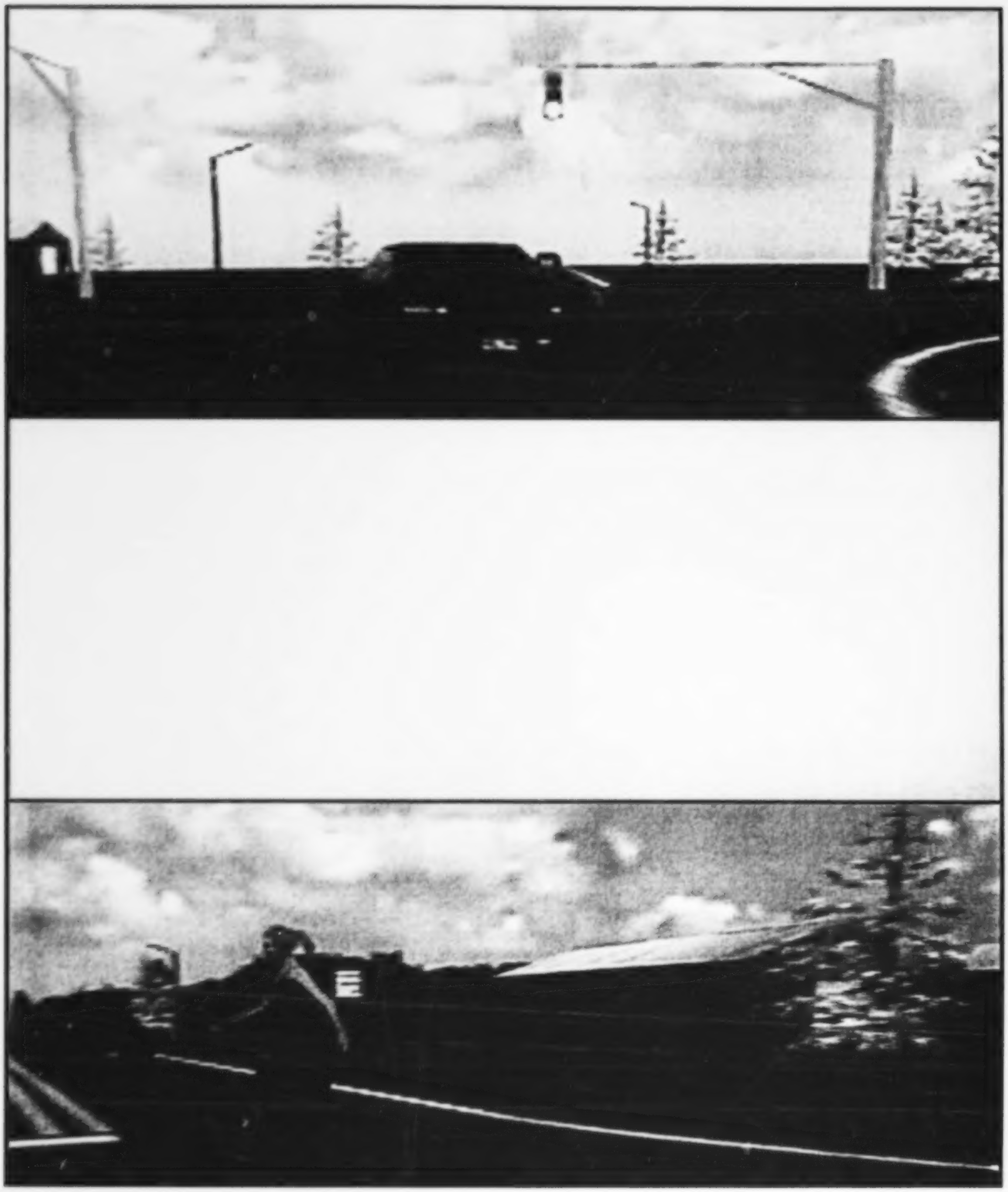


Figure 5.4. Dynamic flicker event: approaching intersection (top); screen turns grey for 80 ms (middle); and pedestrian appears and light changes from green to red (bottom).

In the fourth series, which was presented last in both orders, the principal event occurred near the middle of the scenario. Participants navigated two intersections, a right turn at a stop sign and straight through a set of lights, before approaching a third intersection with a green light. The oncoming traffic on the approach to the intersection was spaced 2 to 8 seconds apart and, as participants approached the intersection, a large truck cleared the intersection coming from the opposite direction. The truck blocked the view to the participant's left, where another vehicle approached from and proceeded to run the red light, just behind the truck. At 70 km/h, the participant just missed hitting the car running the red light from the left. The participant's light remained green. Participants continued driving and drove straight through a T-junction with a stop sign before completing the experimental section about 20 seconds later (see Figure 5.1).

5.6 Results

5.6.1 *Participant Characteristics*

The background driver experience questionnaire results are shown in Table 5.1. Mean age and standard deviations for the simulation study are shown. Driving experience is reflective of age. The average kilometres driven per year are higher for the older age group in comparison to the younger age group. Number of violations per year is also higher for the older age group. In addition, the mean number of total accidents is higher for the older age group, which is a reflection of driving exposure. The number of accidents in the past five years is comparable between the two age groups.

Table 5.1 Participant characteristics described by means and standard deviations: mean age, mean number of years driving, kilometres driven per year, number of violations in the past two years, total number of accidents, and number of accidents in the past five years.

Descriptive Measure	Age Group	
	18 to 25	**65 +**
Mean Age (SD)	21 (1.5)	71 (6.3)
Years Driving (SD)	4 (1.5)	52 (9.1)
Km/Year Driven (SD)	12,750 (7,833)	17,750 (13,884)
Number of Violations, Past 2 Years (SD)	0 (0)	1 (1.5)
Total Accidents (SD)	1 (1.4)	3 (1.9)
Accidents in Past 5 Years (SD)	1 (1.2)	1 (1.1)

5.6.2 Perception Response Time

Each participant's perception response time (PRT), in seconds, was determined for each event in the simulation study. PRT was calculated based on any response made by the participants, whether the participants braked or accelerated. PRTs that could not be calculated due to lack of response or because the response was made in advance of an actual event, were not included in the analysis. Table 5.2 outlines the mean and standard deviations for PRT (in seconds), for both age groups and all events.

Table 5.2 PRT means and standard deviations (in seconds) calculated for each event type and for both age groups.

Event Type	Mean Age Group PRTs (s) (SD)	
	18 to 25	**65 +**
Pedestrian (SD)	1.0 (0.4)	1.4 (0.5)
Yellow Light (SD)	0.7 (0.1)	1.2 (0.3)
Flicker – Pedestrian (SD)	0.5 (0.4)	1.1 (0.5)
Vehicle Incursion (SD)	1.1 (0.4)	1.5 (0.3)

Exploratory results used a series of four independent sample t-tests that were performed comparing event type PRT among each age group. Response to the pedestrian event was not significantly different between the young and old age groups, M= 1.0 and M= 1.4, respectively, $t(11) = 0.204$, $p > 0.05$. The means of the two age groups indicate that the older age group responded more slowly and was slightly more variable.

PRT to the yellow light event was significantly different between the age groups, $t(10) = -3.734$, $p = 0.004$, with the younger age group responding to the light change faster ($M = 0.7$) than the older age group ($M = 1.2$). The slower response time for the older age group is consistent with previous research (Caird et al., 2000; Olson and Sivak, 1986) and age-related slowing and cautiousness (Salthouse, 1988).

The response to the flicker presentation and the sudden appearance of a pedestrian was statistically significant, $t(10) = -2.477$, $p = 0.033$, again with the younger age group responding to the change faster ($M = 0.5$) than the older age group ($M = 1.1$). The slower response times of the older drivers may reflect uncertainty of how to respond to the appearance of the grey mask.

The vehicle incursion was the last event of the experimental trial and PRT was significantly different between the two age groups, $t(12) = -2.542$, $p = 0.026$. The group means are higher than other events for both age groups. The younger age group responded faster to the incursion event ($M = 1.1$) compared to the older age group ($M = 1.5$). Neither group expected a vehicle to violate the traffic control devices at this intersection. Younger drivers responded more quickly to the surprise event than the older drivers.

5.6.3 Participant Actions to Events

In addition to PRT, response type was also recorded for each participant. Table 5.4 outlines the frequency of each response type.

Table 5.3 Response types to critical events by age group.

Age Group	Response Type	Event Type			
		Pedestrian	Yellow Light	Flicker - Pedestrian	Vehicle Incursion
Young	**Braked**	7	5	3	7
	Accelerated	1	3	5	-
	Braked but struck object	-	-	-	-
	Neither Braked nor Accelerated	-	-	-	1
Old	**Braked**	8	2	5	4
	Accelerated	-	6	1	-
	Braked but struck object	-	-	-	2
	Neither Braked nor Accelerated	-	-	2	2

The pedestrian event was the first event encountered by all participants. The pedestrian crossed the road from behind a traffic light standard on the right-hand side of the road (see Figure 5.1). Most of the younger participants braked to decelerate before turning right at the intersection. The appearance of the pedestrian caused the participants to increase their braking. One participant, travelling at a lower speed, initiated a rolling stop, waited for the pedestrian to clear the lane and then accelerated. All eight of the older participants, in contrast to the younger participants, initiated braking well in advance of the approaching intersection. The older participants chose to slow down considerably and wait for the pedestrian to completely cross the road before proceeding with the turn. In all cases, both age groups waited for the pedestrian.

The yellow light intersection contained a traffic light that changed from green to yellow when participants drove through a trigger 40 m in advance of the intersection. At 70 km/h, participants had two seconds to react to the changing light. A greater proportion of younger participants (5 participants) responded sooner to the yellow light event, consequently stopping for the light. Three participants responded by accelerating through the light, perhaps because of a greater approach speed, or perceiving that they did not have enough distance to stop. The older participants were more likely to proceed through the light (6 participants), compared to only two older participants who chose to stop for the light. The slower perception response time produced a shorter stopping distance for the light. This may explain why a majority of the older participants ran the light.

An exploratory test of the dynamic flicker method was adapted to the simulation environment. Participants were asked to make a left-hand turn, during which a grey screen was presented for 80 ms. After the grey screen had appeared and then disappeared, a pedestrian appeared crossing the road in front of the participant's vehicle. The flicker presentation in the dynamic simulation produced interesting response actions. In the younger age group, 5 participants decided to accelerate after the 80 ms grey screen flicker. The tendency to accelerate may have coincided with the sudden detection of the pedestrian or may have been because of the initial speed of their vehicle. Thus, their decision was to beat the pedestrian through the intersection. Three of the younger participants chose to stop after the flicker presentation, possibly after detecting the pedestrian. Five of the older participants chose to stop after the flicker presentation to avoid hitting the pedestrian. One participant chose to accelerate through the intersection, again possibly trying to beat the pedestrian or to complete the turn. Two of the older participants did not make a response. These two participants neither accelerated nor braked upon presentation of the 80 ms grey screen. The low take-off speed of the turn allowed the pedestrian sufficient time to cross in front of their vehicle. None of the participants in either age group struck the pedestrian.

The vehicle incursion event involved the participants approaching the intersection with oncoming traffic. A vehicle from the left violated the red signal and crossed the intersection. In total, seven of the younger participants braked upon viewing the vehicle incursion. Only one participant failed to make a response – neither braked nor accelerated – and the incurring vehicle passed in front. For the older participants, four decided to brake for the incurring vehicle. Two older participants attempted to brake, but because of their approach speed and the late detection of the incurring vehicle, they broadsided the car. Another two older participants failed to make a response altogether. They allowed the violating car to pass in front of their vehicle.

5.7 Discussion

This research study assessed the perception response times (PRT) of older and younger drivers in a number of challenging intersection scenarios. Known driver difficulties with intersection decisions from the change blindness study were adapted and incorporated into the dynamic environment. We again expected that younger and older drivers would have difficulties at intersections, but that older driver performance would be lower in the dynamic setting due to age-related cognitive and visual declines. PRT at the four experimental intersections was expected to be lower for younger participants. Another focus of this study was the adaptation of the 80 ms inter-stimulus interval used in the previous phase of research. Response actions and PRTs were the central focus of analysis.

Overall, PRTs were lower for the younger age group compared to the older age group. Other researchers have exhaustively studied PRTs and this study found similar effects to previous research (Lerner, 1994; Ranney & Simmons, 1993; Olson & Sivak, 1986). A PRT difference was not found for the pedestrian event. This could have been due to a variety of contextual reasons. The intersection at which the pedestrian appeared contained other traffic, but failed to replicate completely the complexity found in real intersections outlined in the previous study. Participants had enough time to detect the pedestrian and allow that pedestrian to cross without a great performance decrement. Detection of the pedestrian could have been due to the non-fluid walking motions of the pedestrian, drawing attention to the pedestrian (e.g., see Cutting, 1982; Johansson, 1973).

5.7.1 Late Yellow Light

Greater PRT performance differences between age groups were seen in the yellow light scenario. The majority of the younger participants stopped for the late changing light. Younger participants detected the changing state of the light sooner than the older participants, which allowed for faster decisions. The younger participants who decided to accelerate through the light exhibited riskier behaviour regardless of the detection times. Older participants, upon detection of the light change, decided to continue on their path. These results are contradictory to the expectation that younger drivers are more willing to run yellow lights (Ebbesen et al., 1975; 1977). The results suggest that despite cautious strategies adopted by older drivers (e.g., driving slower), the capability to respond under time constraints is limited, and the decision to continue through the intersection is indicative of their inability to respond to the light quickly.

5.7.2 Flicker Adaptation

The introduction of a grey mask for 80 ms in the third scenario is a dynamic extension of the modified flicker method. Younger participants were more inclined to accelerate after the presentation of the stimulus, perhaps to beat the suddenly appearing pedestrian or to complete their turn. The lack of a braking response by the younger participants suggests that they may not have detected the pedestrian or that they anticipated that they would miss the pedestrian. The flicker may have disrupted their cohesive visual construct of the intersection and increased the scanning effort to detect the pedestrian. Three of the younger participants made the correct response by stopping for the pedestrian. These participants may have detected the pedestrian sooner than their counterparts. The older participants generally braked for the pedestrian. Through an adopted strategy of driving slower, the older participants may have given themselves a greater time period to scan the environment after the flicker. The older participants who did not respond may have been uncertain about what was happening when the flicker occurred. Once the flicker was over, those objects in motion, namely the pedestrian, were quickly differentiated from objects not in motion. The use of the dynamic flicker method to create effortful search may only be useful for determining search difficulties for static objects.

5.7.3 Vehicle Incursion

The vehicle incursion provided a mixture of responses across age groups. Most of the younger participants braked for the incurring vehicle, a correct response in this instance. One younger participant did not make a response, but was travelling slowly enough to allow the incurring vehicle to pass in front. The older participants showed different responses to the incurring vehicle. Because of the adaptation of generally driving slower, four of the older participants were able to detect the incurring vehicle and make a braking response. Moreover, two older participants did not make a response because they were driving slow enough for the vehicle to cross far ahead of them. Two participants struck the incoming car. These two participants were also exceeding the posted speed limit and did not allow enough stopping distance to avoid the incoming vehicle. Their limited time to respond at their higher speed resulted in no time to respond and thus, they crashed.

5.7.4 Dynamic Flicker Method

The adaptation of the change blindness intersections to the dynamic simulated environment shows some promise. Driver performance decrements have been shown in this pilot phase of research. The installation of a flicker into the dynamic simulation environment has the potential to determine specific scanning difficulties in complex scenarios. In general, the younger age group outperformed the older age group at most of the intersections. Further refinement of the presentation format of flicker is needed to see whether there are performance decrements consistently across age groups. The use of the driving simulator provided a means to monitor actions by all participants and the limitations of drivers of all ages.

6. CONCLUSIONS AND RECOMMENDATIONS

1) The scope and depth of the three studies in combination provide a multi-method approach to acquire a greater understanding of the general and specific driver performance issues at intersections. The focus groups, change blindness study, and the driving simulation study confirm quantitatively and qualitatively that older drivers are concerned about intersections, fail to detect information and hazards with increased age, and do not respond as quickly as younger drivers when critical events occur.

2) To determine the extent of general intersection difficulties and compensation strategies used by older drivers, several focus groups were conducted. The objective of these focus groups was to understand the difficulties that older drivers face each day to be mobile. A variety of adaptations to overcome these hindrances were discussed, such as not driving at night and avoiding problematic maneuvers. As a general method, focus groups provide extensive detail about older driver mobility and safety concerns.

3) The modified flicker method (MFM) was developed to understand driver selective attention at intersections. The MFM provides a driver a turn goal (i.e., right, left or straight) and a limited time to determine whether the turn is safe. The 10 intersections, where age and/or time are predictive of turn decision accuracy, could be used as a diagnostic test for older drivers. In contrast, the flicker method, when used to understand visual attention and cognition, does not provide the observer with a relevant goal or limit the time to view alternating images. Instead the focus is on whether a change is detected.

4) The goal of the MFM was to create a means by which older drivers could be diagnostically assessed for attentional search. Similarly, worst-case designs for intersections could be tested to determine whether drivers' visual attention can adequately scan for salient information to make safe turn decisions. Training drivers to scan for expected and unexpected information and hazards is a logical extension of this research. Future research is required to determine the viability of these three applications.

5) The driving simulation study confirmed and extended previous older driver performance research at intersections. The driving simulation study was the first complete experiment in the University of Calgary Driving Simulator (UCDS). The technical development, system integration, and validation of UCDS took six months to complete. With the integration of the six movement system, significant contributions in transportation human factors, traffic safety, and in-vehicle intelligent transportation systems (ITS) are expected.

6) The relative risk of being in an intersection accident increases dramatically after the age of 75. Why this occurs from a driver performance level of analysis requires additional research. Perhaps foremost among possible follow-up questions is how situational limitations interact with compensation strategies. Do older drivers tend to look for signs and signals, and thus are less likely to see other important, but unexpected, cars and pedestrians? Does the strategy lead to potential intersection conflicts? If many older driver intersection accidents are the result of failing to see traffic lights and signs, does this indicate a failure to adopt a strategy, or that other events in the intersection momentarily cause the search strategy to be suspended or forgotten?

7) Can what is known about older drivers' attention limitations at intersections facilitate the development of in-vehicle ITS countermeasures? A number of possible technologies are being developed to help drivers avoid collisions. These include vision enhancement systems (VES), collision warning systems (e.g., auditory, haptic, visual), and navigation systems. Each system has potential advantages and disadvantages (see Caird, in press). Based on this research, the important design principles of any intersection ITS application should include: complementing existing (and potentially unreceptive) scan strategies; adding time to make adequate decisions; simplifying and prioritizing expected intersection information; and increasing the driver's capability to detect unexpected events within a limited window of time. Research on the design details and necessary trade-offs is needed.

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Appendix A: Research Summaries of Useful Field of View (UFOV) and Driving Accident Studies

Author(s) & Year	Objectives	Methods				Results & Conclusions
		Participants	Independent variable	Dependent variable	Procedure	
Owsley, Ball, Sloane, Roenker, & Bruni (1991)	Examine how accident frequency in older adults relates to various visual and cognitive functions.	N = 53 (M = 70; 26 male, 27 female). All were licensed drivers with a minimum of 1000 miles driven per year.	Age (57-83 years)	Eye health: central and peripheral vision problems; ocular media problems Visual function: visual acuity, contrast sensitivity, disability glare, stereopsis, colour discrimination, visual field sensitivity UFOV Mental status: Mattis Organic Mental Status Syndrome Examination (MOMSSE) Questionnaire: driving history, habits Driving data: state reported accident history	All visual and cognitive tests were administered in a single experimental session.	Serious impairments of central vision or ocular media were associated with driving avoidance. This avoidance, however, was not related to crash involvement. Only mental status, UFOV, and disability glare were significantly related to crash involvement. Taken together, the UFOV and MOMSSE accounted for 20% of the variance in crash frequency (all types) and 29% of the intersection accident variance. Individuals with failing scores on the UFOV were experienced [illegible] times more accidents than those who passed. Those with high MOMSSE scores were [illegible] times more likely than those with low scores to be involved in vehicle accidents. Measures of eye health and visual function were related to UFOV scores but were not directly related to accident involvement.

Author (s), Year	Objectives	Methods				Results & Conclusions
		Participants	Independent variables	Dependent variables	Procedure	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]	[illegible]	[illegible]				[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]

Author (s), Year	Objectives	Methods				Results & Conclusions
		Participants	Independent variable	Dependent variable	Procedure	
Scialfa, Thomas & Joffe (1994)	To study age differences in UFOV using target lines presented in periphery.	N = 12 young adults (M = 24 yrs), N = 9 older adults (M = 64 yrs). Participants were provided with lenses to correct for acuity.	Age group (young, older) Target eccentricity (4, 8 and 14 degrees) Distractor type (none, homogeneous, or heterogeneous)	Eye movements Reaction time to target Response accuracy	Participants were tested in a single session. A brief questionnaire was completed followed by tests of visual functioning. Acuity was corrected using a lens set. The trials began with a fixation point followed by the search display. Participants were instructed to respond (i.e., target present? yes or no) as fast as possible but maintain a high accuracy level. Response feedback was given after each trial.	Older participants had more difficulties locating peripheral targets, especially embedded in heterogeneous distractors. The greater effects of eccentricity and distractor type found in RT of older participants were eliminated when saccade number was partialled out. This finding shows that older adults use a larger number of saccades during search tasks which suggests that these tasks are completed in a serial fashion rather than parallel.

Author (s), Year	Objectives	Methods				Results & Conclusions
		Participants	Independent variable	Dependent variable	Procedure	
Fisk, Owsley & Pulley (1997)	To estimate the prevalence of driving after stroke and to determine whether stroke survivors receive advice and driving evaluations.	N = 290 (160 male, 130 female; M = 66 yrs). All participants were between 3 months to 6 years post-stroke and were drivers before the stroke	Materials: Ss were given an extensive survey Post-stroke driving status (driver / non-driver)	Functional Independence Measure (FIM) Post-stroke driving exposure Driving advice / evaluation after stroke	Survey was administered in two phases. Phase I was a written survey sent out by mail. Phase II was a telephone survey.	Thirty percent of respondents resumed driving after the stroke; of these, one quarter were habitual drivers (100-200 miles per week) and more than one third had low exposure (less than 25 miles per week). Forty-eight percent of participants did not receive any advice about driving following the stroke. Those that did, most often received it from physicians and family members. The majority (87%) did not receive any post-stroke evaluation. Of those that did, 8% had a vision test and 5% had an in-vehicle test. Participants with low FIM scores (i.e., greater degree of impairment) were less likely to be post-stroke drivers.

Author (s), Year	Objectives	Methods				Results & Conclusions
		Participants	Independent variable	Dependent variable	Procedure	
James, Wochinger, James, & Boehm-Davis (1997)	To determine the relative contribution of visual, perceptual, and cognitive factors to older driver collision detection (p. 1019).	N = 60. Three groups of 20 in younger (26-39, M = 30.5); young-old (65-70, M = 68.4); and older (75-86, M = 76.5) screened for a minimum of 20/40 acuity.	Age group (younger, young-old, older) Crossing car (right, left) Number of crossing cars (1, 2, or 4) Crossing car velocity (25, 35, or 45 mph)	Visual, perceptual, and cognitive test batteries including UFOV Conflict present (yes or no) Conflict location (right, left)	Participants were given one intersection training approach in the FHWA TF HRC's video simulator lab (VIDSim). Each simulated approach was to cross intersection where the cross road was a four lane divided and approach a two lane at 35 mph. Two seconds from the center of the intersection the approach terminated and participants responded by pressing either a button on the right or left of the steering wheel. Thirty-six unique approaches were randomly presented 4 times. The uniqueness of approaches was not described.	Visual, perceptual and cognitive test batteries predicted accuracy and errors in the intersection approaches (R2 = 0.10-0.30) for all age groups. The perceptual battery was most predictive of recognition error rates in the young and young-old groups whereas the visual test battery was the most predictive in the old age group.

Author (s), Year	**Objectives**	**Methods**				**Results & Conclusions**
		Participants	**Independent variable**	**Dependent variable**	**Procedure**	
Ball, Owsley, Stalvey, Roenker, Sloane & Graves (1998)	To examine the association between visual and cognitive impairment in older drivers and their avoidance of potentially challenging driving situations.	N = 257 older adults (M = 70 yrs, 137 males, 120 females).	Case controlled design Accident history (0, 1, 2, 3, 4 or more) Age Group (55-59, 60-64, 65-69, 70-74, 75-79, 80-84, 85+) Functional Impairment (6 groups formed on basis of certain combinations of visual and UFOV impairments) Avoidance Situation (rain, night, heavy traffic, rush hour, high speed roads, driving alone, left turns across traffic)	Visual function: visual acuity, contrast sensitivity, visual field sensitivity Eye health: central and peripheral vision problems, ocular media problems Cognitive function: Mattis Organic Mental Status Syndrome Examination UFOV (all 3 sub-tests) Questionnaire: Driving exposure, habits / avoidance of potentially challenging driving situations, accident history	All measures were administered in a single experimental session. A detailed protocol was not provided.	Older drivers who had more severe visual and cognitive impairments reported more avoidance of challenging driving situations and also less driving exposure. Analyses showed that avoidance patterns were different across functional impairment groups. Drivers with a history of at-fault crashes reported more avoidance than those with crash-free records.

Author (s), Year	Objectives	Methods				Results & Conclusions
		Participants	Independent variable	Dependent variable	Procedure	
Goode, Ball, Sloane, Roenker, Roth, Myers & Owsley (1998)	To examine the utility of various common cognitive and perceptual tests in comparison to UFOV in predicting accidents in older drivers	N = 239 (112 female, 127 male, M = 70 yrs). All participants had been in at least one accident in the previous 5 year period. Participants were screened for acuity at a minimum of 20/50.	Case controlled design Accident type (injury, non-injury, control) Age group (55-59, 60-64, 65-69, 70-74, 75-79, 80-84, 85+) At-fault crashes (0, 1 or more) (obtained from State records)	Mattis Organic Mental Syndrome Screening Examination (MOMSSE), Trail Making Test, Weschler Memory Scale (Visual Reproduction Subtest), Rey-Osterrieth Complex Figure Test, UFOV. Crash status	All tests were administered in a single session.	Three models were used to assess the predictive ability of the tests used. The first included all tests except the UFOV. These tests were able to successfully classify 58.6% of crashers and non-crashers. When UFOV was included in the test battery, the success rate was 77.4%. When UFOV alone as used as a predictor, the success rate 85.4%.

Author (s), Year	Objectives	Methods				Results & Conclusions
		Participants	Independent variable	Dependent variable	Procedure	
Owsley, Ball, McGwin Jr., Sloane, Roenker, White & Overley (1998)	To explore associations between measures of visual processing ability, including UFOV, and crash involvement in older drivers.	N = 294 (158 male, 136 female)	Case controlled design Accident history (0, 1, 2, 3, 4 or more) Age Group (55-59, 60-64, 65-69, 70-74, 75-79, 80-84, 85+)	Number of accidents in follow-up period Visual measures: Acuity, Contrast sensitivity, Steroacuity, Disability glare, Visual filed sensitivity UFOV Mattis Organic Mental Syndrome Screening Examination (MOMSSE) Medical self-report Driving questionnaire	Study protocol was completed in a single session. Various visual and cognitive measures were recorded as well as questionnaires and medical histories. After a 3-year period, a follow-up phone interview queried driving history in the interim period.	Two variable were identified as having independent associations with crash risk: Participants with 40% or greater reduction in UFOV were 2.2 times more likely to be involved in a crash in the follow up period and participants who reported driving fewer than seven days a week had a 45% decreased crash rate than did participants who drove daily. UFOV sub-tests were evaluated seperately. Speed of processing impairment and selective attention impairment were not significantly related to crash occurrence. However, divided attention was associated with a 2.3-fold increase in crash risk.

Author (s), Year	Objectives	Methods				Results & Conclusions
		Participants	Independent variable	Dependent variable	Procedure	
Owsley, McGwin Jr. & Ball (1998)	To identify visual risk factors for injury vehicle crashes in older drivers.	N = 294 (159 male, 135 female, M = 71 yrs). n = 78 had been involved in at least one injury accident over 5 yr period. n = 101 were in at least one non-injury accident. n = 115 made up the control group (no accidents).	Case controlled design Accident type (injury, non-injury, control) Age group (55-59, 60-64, 65-69, 70-74, 75-79, 80-84, 85+)	Visual acuity, Contrast sensitivity, Stereoacuity, Disability glare, Visual field sensitivity UFOV Questionnaires: Driving exposure, Medical conditions, Mattis Organic Mental Syndrome Screening Examination (MOMSSE)	All participants completed the visual function test battery in a single session.	Results demonstrated that UFOV and glaucoma were the only significant independent predictors of injurious crash involvement. Odds ratios (OR) for reductions in UFOV of 23-40% were 4.2 greater than for UFOV scores of less than 23%, were 13.6 greater for reductions of 41-60%, and were 17.2 greater for reductions >60%. OR for glaucoma was 3.6. UFOV impairment was the only variable independently associated with non-injurious crash involvement.

Author (s), Year	Objectives	Methods				Results & Conclusions
		Participants	Independent variable	Dependent variable	Procedure	
Sims, Owsley, Allman, Ball & Smoot (1998)	To examine association between medical and functional variables and at-fault accidents in older drivers.	N = 174 (57-91, M = 71 yrs). n = 99 were drivers who had had at least one at-fault crash in previous 6 yrs. n = 75 made up control group with no at-fault accidents during same time period.	Case controlled design Accident history (0, 1, 2, 3, 4 or more) Age Group (55-59, 60-64, 65-69, 70-74, 75-79, 80-84, 85+)	Questionnaires: Medical history, Prescription info, Center for Epidemiological Studies -Depression Scale, Short Michigan Alcoholism Screening Test, Hearing function, Daily functioning, Driving habits. Physical Exam and Performance Measures: Blood pressure, Urine test, Performance-Oriented Mobility Assessment, Timed walk, Bilateral grip strength, Mattis Organic Mental Status Syndrome Examination (MOMSSE), Hearing, Visual acuity, Contrast sensitivity, UFOV.	Procedural information is not described.	Crash involvement was associated significantly with African-Americans, difficulty reaching out, not using beta-blocker, alpha-blocker, or diuretic, positive urinary opiates, falling in the previous 2 yrs, and failing the UFOV test. Among continuous variables, significant associations with accidents included older age, poorer visual acuity, contrast sensitivity, and performance on the MOMSSE. Driving exposure did not differ significantly across accident history. The association between UFOV and accident involvement was consistent with previous findings.

Author (s), Year	Objectives	Methods				Results & Conclusions
		Participants	Independent variable	Dependent variable	Procedure	
Chaparro, Groff, Tabor, Sifrit & Gugerty (1999a)	To examine the relationship between UFOV and measures of situational awareness (SA).	N = 25 (18 to 82 yrs). All were licensed drivers.	Apparatus: DriveSim Software was used to test SA. DriveSim and UFOV tests were run on a desktop PC.	Corrected visual acuity Number of cars correctly recalled (by location) Number of hazards correctly avoided Signal detection rate (correct responses on hazard trials versus catch trials) Recall error UFOV scores (Sub-tests 1-3)	Participants completed a background questionnaire and were tested for visual acuity and UFOV. Participants were presented with 3-D scenes from inside a car. While driving through short roadways, participants were instructed to monitor the number and location of all other vehicles and to avoid collisions. Half the scenarios had hazards and the others were catch trials. After each scenario, participants were asked to recall the number and location of vehicles using an overhead map.	UFOV sub2 and UFOV sub3 were significantly correlated with accident involvement ($r= .52$, $p=.01$; $r=.83$, $p<.001$) and participants' ability to recognize and react to hazards ($r=.33$, $p<.01$; $r=.66$, $p<.001$). Corrected visual acuity was not correlated with measures of UFOV or SA. Participants who scored higher on UFOV sub2 & 3 were more successful at identifying and avoiding hazards. Results suggest that UFOV may be an important factor in monitoring the dynamic driving environment. Similar results are reported in Chaparro, Groff, Tabor, Sifrit & Gugerty (1999b).

Author (s), Year	Objectives	Methods				Results & Conclusions
		Participants	Independent variable	Dependent variable	Procedure	
Owsley, Stalvey, Wells & Sloane (1999)	To examine the role of cataract in older drivers.	N = 379 (55 to 85 yrs). n = 279 were diagnosed with cataract in one or both eyes, had acuity of 20/40 or worse, and had not had surgery on cataract. n = 100 were controls, with no diagnosis of cataract, acuity of 20/25 or better in each eye, and free of identifiable eye disease	Cataract (present, not present)	Driving Habits Questionnaire: Exposure, Dependence on other drivers, Driving difficulty, Driving space, Crashes and citations, General health, mental status, Depression Acuity, Contrast sensitivity, Visual field sensitivity Crash data (not self-reported)	The testing protocol was divided into two parts, interview and visual functional assessment	Older participants with cataract were approximately two times more likely to report reduced driving exposure, driving slower than traffic flow, and preference for someone else driving. They were four times more likely to report difficulties with challenging driving situations such as driving in the rain or at night. Participants with cataract were 2.5 times more likely to have a history of at-fault accident involvement in previous 5 year period

Author (s) Year	Objectives	Methods				Results & Conclusions
		Participants	Independent variable	Dependent variable	Procedure	
Pringle, Kramer, Irwin & Atchley (in press)	Examine ability to detect changes in complex real-world scenes. Relates to individual differences in attentional breadth.	N = 20 young adults (M = 21 yrs); N = 20 older adults (M = 68 yrs). All Ss had minimum 20/40 corrected visual acuity, average monthly mileage > 25 miles and had held a driver's license for more than 5 years.	Age group (young, older) Salience of target (high, low) Meaningfulness (high, low) Eccentricity (central, periphery)	Attentional breadth (UFOV) Perceptual change detection RT	Participants were presented with flicker paradigm task. Images were presented on a computer. The computer alternated 2 original and 2 modified scenes (with gray blank fields in between each image). Participants pressed a button when a change was detected and then reported the nature of change to experimenter.	A significant correlation was found between UFOV and change detection RT ($r = -0.68$, $p < 0.01$). Smaller UFOV was related to slower detection.

Appendix B: Summary of Change Blindness Studies

Author (s), Year	Central Research Question	Methods				Results & Conclusions
		Participants	Independent variable(s)	Dependent variable(s)	Procedure	
Rensink, O'Regan & Clark (2000)	To examine the mechanism behind induced change blindness, specifically, its dependence on initial preview and the nature of interruptions used. Two experiments formed the complete study.	N = 10 in each experimental condition. No details given.	(1) Extended Preview Preview type (0 = preview, 1 = no preview) Change type (presence, colour, location) Interest level (central, marginal)	Response time (s) Number of alternations of images (#)	Participants were presented with alternating or flickering images in which some element of the image changed from one scene to the next (termed the flicker paradigm (A, A', A, A', A', ...)). All images were presented for 240 ms with an inter-stimulus interval of (ISI) of 80 ms (blank). Participants were presented with a blank gray screen; participants were presented with an 8 second preview of the initial image and were asked to respond the [illegible] of a change and report verbally once a change was detected. Changes were varied in terms of presence, colour, or location as well as in terms of interest level (central or marginal as rated by independent observers). Results were compared to previous findings without preview interval.	No preview effect was found. The authors concluded that change blindness is not caused by insufficient time to construct a coherent representation of image either, it is the result of some perceptual and/or attentional deficiency.

Author(s) (Year)	Central Research Question	Method				Results & Conclusions
		Participants	Independent variables	Dependent variables	Procedure	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
			[illegible]	[illegible]	[illegible]	[illegible]
			[illegible]	[illegible]	[illegible]	[illegible]

[illegible]	[illegible]	[illegible]				[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Author(s), Year	Central Research Question	Methods				Results & Conclusions
		Participants	Independent variable(s)	Dependent variable(s)	Procedure	
Pringle, Kramer, Irwin & Atchley (in press)	To examine the ability to detect changes in complex real-world scenes. Relates to individual differences in attentional breadth.	N = 20 young adults (M = 23 yrs); N = 20 older adults (M = 68 yrs). All Participants had minimum 20/40 corrected visual acuity, average monthly mileage > 25 miles, had driver's license for more than 2 yrs.	Age group (young, older) Salience of target (high, low) Meaningfulness (high, low) Eccentricity (central, peripheral)	UFOV Response time (s)	Flicker paradigm procedure. Participants pressed a button when the change was detected, then reported nature of change to experimenter.	Perceptual change detection is difficult for both younger and older adults. Older adults, however, have much slower response times on detection tasks. Meaningfulness only benefited performance for younger adults when the change was of low salience. There was a significant 3-way (eccentricity x salience x meaning) interaction (F(1, 38) = 9.68, p < 0.007). Central changes were detected faster than peripheral changes only for high meaning and high salience (p < 0.001). There was a significant correlation between UFOV and response time (r = .0.54, p < 0.01). Smaller UFOV was related to slower detection.

Author(s), Year	Central Research Question	Methods				Results & Conclusions
		Participants	Independent variable(s)	Dependent variable(s)	Procedure	
Rensink, O'Regan, & Clark (1997)	To examine the phenomenon of change blindness. 1) Experiment 1 examined whether the basic flicker paradigm could induce change blindness. 2) Experiment 2 examined whether or not difficulties in change detection were due to time limitations in image processing. 3) Experiment 3 examined whether or not difficulties in change detection were due to reduced visibility caused by the flickering.	N = 10 for each experiment. No details were given.	(1) Standard Flicker Condition Blank Interval (80 ms or none) Interest Level (central or marginal) Change Type (presence, colour, location)	Response Time Number of Alternations	Basic flicker paradigm procedures. All images were presented for 240 ms with an inter-stimulus interval (ISI) of 80 ms where participants were presented with a blank gray screen. Participants were asked to press a button once a change was detected and then state verbally the nature of the change. Central and marginal changes were rated by independent observers.	Changes of marginal interest were very difficult to see (M = 10.9 s) compared to changes of central interest (M = 4.7 s). When the blank interval is absent, all changes were easily detected.
			(2) Extended Display Duration Display Duration (240 ms, 560 ms) Interest Level (central or marginal) Change Type (presence, colour, location)	Response Time Number of Alternations	Same flicker paradigm procedures as in experiment 1. However, the flicker sequence was A, A', A, A', etc. (rather than A, A, A', A'). All images were presented for 560 ms with an inter-stimulus interval (ISI) of 80 ms.	No significant differences were found between the two different display durations (i.e., 240 versus 560 ms). Time constraints in image processing do not appear to impact change blindness.

Author (s), Year	Central Research Question	Methods				Results & Conclusions
		Participants	Independent variable(s)	Dependent variable(s)	Procedure	
Rensink, O'Regan, & Clark (1997) (Continued)			(3) Effects of Cue Validity Cue Type (none, partially valid, partially invalid, completely valid) Interest Level (central or marginal) Change Type (presence, colour, location)	Response Time Number of Alternations	Same flicker paradigm procedures as in experiment 1. In this study, however, a verbal cue was presented for 3 seconds at the beginning of each trial. The cues were either completely valid (naming the part of the scene that changed) or partially valid (divided equally into valid cues and invalid cues).	Valid cues were found to improve response times for both changes of central and marginal interest. Invalid cues caused a slight (not significant) increase in response times. These findings support the conclusion that visibility is not a limiting factor in the detection of changes.
Rensink (2000b)	To examine and test the hypothesis that focused attention is needed to detect change. Study was broken down into 5 sub-tasks (1-5).	N = 12 adult observers with normal or corrected-to-normal vision.	Display size (2, 6, 10 items) Change type (orientation, polarity) 1-2) On-times (80, 160, 320, 480, 640, 800 ms) 4) Variation (static, dynamic)	Response time (s) Search slope (slope of response time over display size) Search rate (inverse of slope) Capacity (alternation time over search slope)	Flicker paradigm procedures (see Rensink, O'Regan, &Clark, 2000). Displays were simple arrays of rectangles. Participants were instructed to respond to the changes as quickly as possible while maintaining high accuracy. All tasks and trials were counterbalanced.	Results for the first sub-task showed that visual search for change is a self-terminating process with a linear relationship between time and the number of display elements. Processing times for both change types were found to be constant for on-times between 80 to 640 ms. Results support the hypothesis that visual search for change involves a limited-capacity process similar to the attentional process used for static patterns.

Author (s), Year	Central Research Question	Methods				Results & Conclusions
		Participants	Independent variable(s)	Dependent variable(s)	Procedure	
Readinger (1999)	To examine the effect of locomotive pathway information on a change-detection task in a virtual reality environment.	N = 10. No details given.	Change type (no change, change - path affected, change - path unaffected)	Response accuracy	Participants viewed scenes of a virtual intersection of two streets with six barriers placed around it. Participants' task was to determine whether paired scenes were identical or not. In altered scenes, the barriers were moved to new locations such that the new formation would or would not impact potential pathway information for the Participants (e.g., blocking a road).	In trials where pathway information was impacted, Participants had 90% accuracy compared to 64% accuracy in trials where path information was not changed. Potential paths of movement through the environment appear to be a factor in observers' stored perceptions of a scene.

Appendix C: Focus Group Consent Form

Title of Investigation: Focus Group on Older Driver Mobility Difficulties

Principal Investigator: Dr. Jeff Caird.

This consent form, a copy of which has been given to you, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, please ask. Please take the time to read this form carefully and to understand any accompanying information.

Description of Research Project:

We are studying the difficulties that older drivers encounter in certain traffic situations. You will be asked to participate in a focus group. A focus group is an informal discussion between 8 to 12 people wherein we will discuss various issues pertaining to traffic situations and driving experiences. Because of the nature of focus groups, you will have control over your own level of participation and will not be required to answer or address each of the issues and questions raised. All of your comments will in no way be linked to your person. It is hoped that such a discussion will better inform upcoming research projects. The discussion group is expected to last approximately 75 minutes.

Informed Consent:

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a participant. In no way does this waive your legal rights nor release the investigators, sponsors, or involved institutions from their legal professional responsibilities. You are free to not answer specific items or questions in interviews or on questionnaires. You are free to withdraw from the study at any time without penalty. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation. If you have further questions concerning matters related to this research, contact:

Dr. Jeff Caird, Department of Psychology, University of Calgary
Fax: (403) 220-5571, jkcaird@ucalgary.ca

If you have any questions not satisfactorily answered by the primary researchers concerning your participation in this project, you may contact the Research Services Office, University of Calgary, and ask for Pat Evans, (403) 220-3782.

______________________________	____________________
Participant	Date
______________________________	____________________
Investigator/Witness (optional)	Date

A copy of this consent form will be given to you to keep for your records if you request it. This research has the ethical approval of the Department of Psychology and the University of Calgary.

Appendix D: Background Driving Questionnaire

1 How old are you? __________

2. Please indicate your gender. M F

3. Do you have a valid driver's licence? Yes No

4. How many years have you had a driver's licence? _________________

5. About how many kilometres do you drive **per week**? _______ kilometres / week

6. About how many kilometres do you drive **per year**? _______ kilometres / year

Please use the following scale to respond to questions 7 through 19.

1	2	3	4	5
never	1-2 times a year	1-2 times a month	1-2 times a week	Every day

7. How often do you drive?	1	2	3	4	5
8. How often do you drive on city streets?	1	2	3	4	5
9. How often do you drive on rural / country roads?	1	2	3	4	5
10. How often do you drive on freeways?	1	2	3	4	5
11. How often do you drive at night?	1	2	3	4	5
12. How often do you drive to take a vacation?	1	2	3	4	5
13. How often do you drive your friends around?	1	2	3	4	5
14. How often do you avoid complex intersections ?	1	2	3	4	5
15. How often do you avoid driving in unfamiliar areas of the city?	1	2	3	4	5
16. How often do you avoid ice and snowy conditions?	1	2	3	4	5
17. How often do you avoid driving during rush hours?	1	2	3	4	5
18. How often do you avoid making quick manoeuvres?	1	2	3	4	5
19. How often do reduce your speed to make sure that your driving decisions are safe?	1	2	3	4	5

20. Do you wear glasses or contact lenses that correct your vision while driving?

Yes No

20a. If so, are they bifocals? Yes No

21. Are you using prescription medications that you have been told will affect your driving?

Yes No

Appendix E: Driving Behaviour Questionnaire

Please answer all the questions in the pages that follow. The words that are used to describe how often you may engage in the various driving behaviours are defined next. If you do the action that is described in a particular question almost all of the time that you encounter that situation, then you should choose Very Often. If you do the action that is described most of the time, Quite Often should be chosen. If you do a behaviour sometimes, you may want to chose On Occasion. Very rarely means that you rarely perform the actions that are described. Never means that you do not do the action that is described. Thank you very much for your participation.

	How often do you...?	Very Often	Quite Often	On Occasion	Very Rarely	Never
1.	Attempt to pass a vehicle that you hadn't noticed to be signaling a left turn	5	4	3	2	1
2.	Run yellow lights	5	4	3	2	1
3.	Fail to notice a pedestrian crossing at an intersection	5	4	3	2	1
4.	Make three right turns to avoid a left turn	5	4	3	2	1
5.	While turning right, nearly hit a cyclist who has come up on your right side	5	4	3	2	1
6.	When approaching an intersection, pay such close attention to the traffic lights that you nearly hit the vehicle in front of you	5	4	3	2	1
7.	Underestimate the speed of an oncoming vehicle while you are turning left	5	4	3	2	1
8.	Have difficulty anticipating the actions of other drivers at a "four-way stop"	5	4	3	2	1
9.	Miss a stop sign and narrowly avoid colliding with traffic having the right of way	5	4	3	2	1
10.	Fail to look in your blindspot before changing lanes and nearly sideswipe another vehicle	5	4	3	2	1
11.	Realize that you have no clear recollection of the road along which you have just been traveling	5	4	3	2	1
12.	Speed up in order to make it through yellow lights	5	4	3	2	1

How often do you...?	Very Often	Quite Often	On Occasion	Very Rarely	Never
13. Almost miss seeing an approaching vehicle at an intersection because you were attending to other vehicles and pedestrians	5	4	3	2	1
14. Yield to other vehicles that are turning although you have the right of way	5	4	3	2	1
15. Fail to see an approaching vehicle because another vehicle blocks your view at an intersection	5	4	3	2	1
16. Honk at a car that has turned too close in front of you	5	4	3	2	1
17. Get into the wrong lane at an intersection and have to change to the right one	5	4	3	2	1
18. Turn into the wrong lane when completing a left turn	5	4	3	2	1
19. Find yourself stopped in the middle of an intersection or in a pedestrian crosswalk because of stopped vehicles ahead	5	4	3	2	1
20. Forget to signal your turn when approaching an intersection	5	4	3	2	1
21. Deliberately disregard pedestrians about to cross or already crossing the road	5	4	3	2	1
22. Not yield to traffic coming from the right at an intersection	5	4	3	2	1
23. Forget which gear you are currently in when a traffic signal changes from red to green	5	4	3	2	1
24. Fail to notice when a traffic signal turns green	5	4	3	2	1

How often do you...?	Very Often	Quite Often	On Occasion	Very Rarely	Never
25. Proceed through an intersection without understanding the meaning of turn signals	5	4	3	2	1
26. Express your emotions toward other drivers because their actions anger you	5	4	3	2	1
27. Fail to check your rear or side view mirrors before changing lanes	5	4	3	2	1
28. Fail to notice that pedestrians are crossing when turning into a side street from a main road	5	4	3	2	1
29. Fail to notice a 'green arrow' at traffic signal allowing you to turn	5	4	3	2	1
30. Find yourself driving too fast when approaching an intersection and have to brake hard to stop	5	4	3	2	1
31. Pull back in behind the vehicle you are passing because you misjudge the distance to the oncoming vehicle while passing	5	4	3	2	1
32. Make an illegal 'U' turn at an intersection	5	4	3	2	1
33. Notice only too late that you drove through a red light	5	4	3	2	1
34. Deliberately run a red light because the cross traffic was still stopped	5	4	3	2	1
35. Honk at a vehicle in front of you because the driver did not turn through a gap in traffic	5	4	3	2	1
36. Have difficulty seeing a stop sign due to rain or snow	5	4	3	2	1
37. Have difficulty seeing traffic lights at dawn or dusk	5	4	3	2	1
38. Stop by mistake at a green traffic light	5	4	3	2	1
39. Turn just in front of pedestrians despite the fact that they have the right of way	5	4	3	2	1

How often do you...?	Very Often	Quite Often	On Occasion	Very Rarely	Never
60. Turn left in front of oncoming vehicles, forcing them to slam on the brakes	5	4	3	2	1
61. Deliberately not stop at 'stop' sign	5	4	3	2	1
62. Deliberately cross an intersection although the traffic lights have already turned against you	5	4	3	2	1
63. Avoid driving at night	5	4	3	2	1
64. Follow another vehicle into an intersection without realizing that the light has changed to red	5	4	3	2	1
65. Slow down because a green light is likely to change to yellow and red	5	4	3	2	1
66. Honk at a vehicle in front of you that has not noticed the light has changed from red to green	5	4	3	2	1
67. Avoid busy or complex intersections	5	4	3	2	1
68. Choose to proceed through a red stoplight when no one is around	5	4	3	2	1

Appendix B: Focus Group Debriefing Form

Thank you very much for your participation. Your assistance has helped us.

The objective of this phase of the project, which is funded by Transport Canada, is to gather qualitative information from older drivers about the types of difficulties commonly encountered in a variety of traffic situations. In particular, we are interested in difficulties that older and younger drivers have with intersections. Each of these driver groups are over-represented in accident statistics for different reasons.

The information provided by participants in each focus group will be used to develop research studies that will test specific difficulties that older drivers have with intersections. In addition, a number of interventions will be tested to determine whether various technologies can assist younger and older drivers make better intersection decisions.

You are welcome to contact us for results or any other information you want regarding this study.

You may contact:

Dr. Jeff K. Caird
Cognitive Ergonomics Research Laboratory
Department of Psychology
University of Calgary
2500 University Drive N.W.
Calgary, Alberta T2N 1N4
(403) 220-5571 (Office)
Email: jkcaird@ucalgary.ca

If you are interested in learning more about older driver programs, or other transportation human factors issues, the following web site offers numerous links:
http://www.psych.ucalgary.ca/PACE/CERL_Lab

Appendix G: Complete Focus Group Comments

Nov. 17, 2000, Focus Group Results by Question

1. How much has driving in Calgary changed over the years?

- Road system in Calgary not keeping up with the growth of the city
- Calgary's climate makes driving difficult (e.g., ice and snow)
- Calgary public transit not adequate for size of city

2. What conditions make you feel uncomfortable while you're driving?

- Changing lanes left to right/right to left to overtake
- Merging
- Rush hour heavy traffic; particularly, keeping up with traffic or changing lanes
- Driving at night
- Roads where two-lane traffic is forced into one lane after a traffic light
- Roads where several others roads feed on and off one main road

3. Can you think of an incident you've experienced or observed that was troublesome?

- One woman witnessed another elderly woman pull into the "X" zone at an LRT crossing; the gate came down on the roof of the woman's car. When the witness got out to see if the driver was OK, the driver admitted to not knowing what the "X" meant
- While going east on McKnight Blvd N.E., two lanes narrow to one after the 36 St lights, making it difficult to not get caught in the right-hand lane if one doesn't change lanes quickly enough
- A man stopped at a red light on Memorial Drive S.E. heard a bang and then realized that a woman coming from the other direction had been hit and her car turned around 90 degrees in the intersection so she was facing the wrong way; the car who hit the elderly woman drove off without stopping
- Dual left turns at controlled intersections when the cars in the left lane pull into the right lane, cutting off the drivers turning from the right lane (e.g., 11 St and 6 Ave S.W.)

4. Can you describe what makes an intersection good or bad?

- Intersections where driver is required to merge uphill
- Intersections where driver must yield before pulling onto a road with fast-moving traffic (feel it should be a merge lane not a yield as there is no time or room to get up to speed)
- Placement of stop signs often seems too far back from the intersection to see what is going on; usually trees or other cars block view
- Roads like Memorial Dr at Deerfoot Tr N.E., the Crowchild Tr. bridge over the Bow River, and the 4 St. fly-over off Memorial Dr into downtown were confusing and difficult to navigate because there were too many roads entering and exiting onto one road; also, these roads often had too many signs
- A few felt the printing on traffic signs was too small to read
- Several felt traffic signs weren't consistently placed from one intersection to next, making navigation somewhat frustrating

5. Is there anything you do to keep up with driving changes or to stay safer on the road?

- Wait a little longer at green lights to make sure intersection is clear
- Two participants no longer drove at night
- Three chose not to drive during rush hour if possible
- One no longer drove downtown
- Two took the Alberta Motor Association's seniors' driving course
- One tried to drive mostly during non-busy times, but felt the roads were busy most of the time now
- Most leave early in order to get where they're going on time
- One gives herself a "pep talk" before getting on the road and reminds herself to "stay calm and smart" while driving

- One will often drive "miles out of the way" to avoid merging

Other problems/concerns/comments that arose during the focus group

- A few experienced arthritis problems and found it difficult to shoulder check or hold onto the steering wheel for long periods of time
- Two people mentioned specifically that older drivers required more than just an annual medical to determine fitness; they suggested driver's tests and thorough medical exams performed by an impartial doctor.

Nov. 30, 2000, Focus Group Results by Question

1. What makes you uncomfortable when you're driving?
- Driving in bad weather (snow, rain, fog)
- Left-hand turns; most difficulties were related to unprotected left turns
- Driving behind trucks or vans because of impeded vision
- Driving after having not driven for several days or weeks
- Being forced to drive above the speed limit to stay with the other traffic
- Driving at night
- Stopping on a hill when it's icy

2. Has there ever been a time when you needed to drive, but you chose not to because you felt uncomfortable going out on the road?
- During bad weather

3. Can you describe in detail a time when you deliberately drove out of your way to avoid a certain type of road condition?
- One couple described driving extra distance to avoid making a left turn onto a busy road that doesn't have lights; instead they drove through their neighbourhood to the next main road so they could turn at the lights

4. Can you think of an incident you've experienced or observed that was troublesome?
- One person ran into a road barrier after the truck he was following pulled quickly into the other lane to avoid it. He did not have enough time to change lanes or stop before hitting the barrier.
- One driver was turning left from 33 Ave onto 14 St without an advance signal and was nearly hit by another car
- One driver gets confused at Richmond Rd and Sarcee Tr after leaving home; she often gets turned around because the roads are hard to follow and ends up heading back towards her own house instead of where she wants to go
- One driver turns into the Taco Bell on 16 Ave N.W. at Home Road so she can drive straight through the intersection at Home Road instead of trying to turn left onto it without an advance light

5. Can you describe intersections you find difficult to navigate in Calgary and why?
- Richmond Rd and Sarcee Tr: confusing, too many roads
- 17 Ave and 14 St S.W.: no left turn allowed onto 17 Ave from 14 St
- Bow Tr and 33 Ave: no protected left turn going west
- 17 Ave and 8 St: new meters on the right force drivers to switch quickly into left lane after the light; no advance warning that it narrows to one lane
- 19 St and John Laurie Blvd N.W.: too difficult to make a left turn onto John Laurie because traffic is moving too fast and there are no lights
- 16 Ave and Home Road N.W.: awkward left turn with no advance light

6. What steps do you take to keep your driving skills current or to make yourself feel safer on the road?

- One person no longer drove at night because of tunnel vision; he also had his vision tested annually
- One took the Alberta Motor Association's course for older drivers
- One couple drives to a controlled intersection in their neighbourhood to make a left-hand turn instead of using a closer, uncontrolled intersection

Other problems/concerns/comments that arose during the focus group

- Stop signs too far back from the intersection
- One person felt billboards were distracting when trying to read road signs
- Some felt playground and school zone signs were not well placed, often being hidden by trees
- Several found street signs difficult to read and felt they could have bigger text (especially the small street name signs in green)
- One mentioned preferring the advance turn light to be on the centre pole rather than on the same hanging pole as the red light; they felt a flashing green light next to the red was not as obvious because most drivers were looking at the red
- One person suggested older drivers required more than just an annual medical to determine fitness; others in the group agreed and they suggested driver's tests and thorough medical exams performed by an impartial doctor

Appendix H: Change Blindness Experimental Protocol

General Instructions

Welcome Participant – Introduce self

Provide participant with informed consent

Thank you very much for participating in this study. It should take about one hour to complete. I would like to remind you that you are free to withdraw from this study at any time. Please look through the informed consent. If you have any questions, please do not hesitate to ask.

Participant reads / signs form

Do you have any questions?

To begin with, I will ask you to fill out this brief background driving questionnaire. If you have any questions, let me know.

Participant fills out questionnaire

Now I will assess your visual acuity and contrast sensitivity. This is just to get an idea of your general visual status.

Test visual acuity. Record.
Test contrast sensitivity. Record.

Today I will show you a number of pictures that were taken from a driver's point of view. We are interested in how people make turn decisions. I will show approximately 50 intersections and ask you to respond as you would when you ordinarily drive.

Equipment set-up

Please have a seat in the simulator. We can adjust the height of the seat to your comfort. We can also move the simulator closer or farther if you like.

*Make necessary adjustments. (*Note: **do not move chair**, move simulator instead)*

GENERAL INSTRUCTIONS

To start, we'll run through 6 intersection images to familiarize you with the simulator set-up. The intersection pictures will appear on the screen in front of you.

The first screen you see tells you which direction you will travel at the intersection. You will see either a left, a right or a straight ahead arrow. The second picture you see will be the intersection. It will flash on and off for 5 or 8 seconds. Once the intersection begins to flicker, you will need to decide whether you will go or not go in the direction that was indicated. After the scene stops flickering, you should press the accelerator if you choose to go. If you decide that it is not safe to go, you should press the brake. Once you have pressed either the brake or accelerator, you should place your foot back on the floor. *(Indicate where.)*

Once you have memorized in which direction you will be traveling, you should press the button on the steering wheel to view the intersection.

Once the intersection begins to flash on and off, you should make your decision just as you would when you drive your own vehicle.

Once you have pressed either the brake or accelerator, a blank screen will be shown with a few questions about what influenced your decision.

At the conclusion of watching the intersection, you should indicate whether you would go, with the accelerator, or not go, with the brake. In addition I will ask you a number of questions about what you saw.

If during the presentation of an intersection you forget which direction you are supposed to go, just let me know. Do look at the directional arrow on the first screen long enough to remember which direction you are to travel.

If you are not sure what you are supposed to do at any time just let me know.

PRACTICE TRIALS

The purpose of showing you a number of practice trials is to make sure that you understand what you are supposed to do.

Once the intersection begins to flash on and off, you should form a decision whether to go or not to go, just as you would when you drive your own vehicle. At the conclusion of the flashing scene, if you choose to go, you should press the accelerator, and if you decide that it is not safe to go, you should press the brake.

Go Through Right Turn, Left Turn, Straight Ahead, Go/No-Go Situations + Uncertain Intersections
[*Place the responsibility for interpretation of what to do with the participant*]

Once you have pressed either the brake or accelerator, you should place your foot back on the floor. *(Indicate where.)*

This is the end of the practice intersection images.

EXPERIMENTAL TRIALS

When you are ready, you may begin the experimental intersection images by pressing the button on the steering wheel.

Once the intersection begins to flash on and off, you should form a decision whether to go or not to go, just as you would when you drive your own vehicle. At the conclusion of the flashing scene, if you choose to go, you should press the accelerator, and if you decide that it is not safe to go, you should press the brake.

Once you have pressed either the brake or accelerator, you should place your foot back on the floor. *(Indicate where.)*

If no response, ask whether they would have gone or not.

If you need to take a short break, just let me know.

Go Through Experimental Trials.

After each trial, ask questions about intersection information that affected their turn decisions.

Record as much verbal information as possible and clarify, as needed (e.g., which element was the primary contributor to your decision?) Repeat more towards the end of trials.

Check to see that participants place their foot back on the floor after every trial.
If not, remind them.

Show experimental block. Record responses to questions on Verbal Data Form.

End of Experimental Trials

Now I will ask you to fill out this questionnaire regarding aspects of the study. It will only take a few minutes to complete.

1) Hand out Driver Behaviour Questionnaire. Allow participant to complete form.
(Clarify questions if needed.)

2) Give participant debriefing form. Go through form with participant.

3) Ask questions about what they thought about the study.
Write responses on qualitative form.

4) Log Bonus Credit for Participation Pool

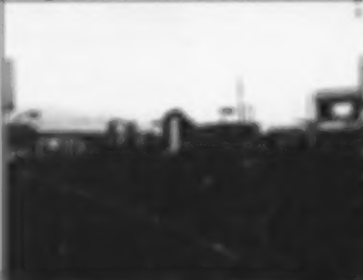
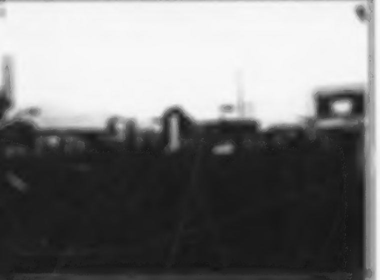
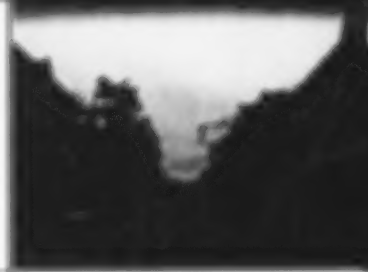
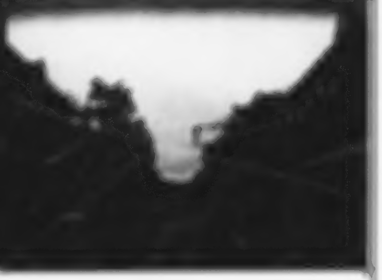
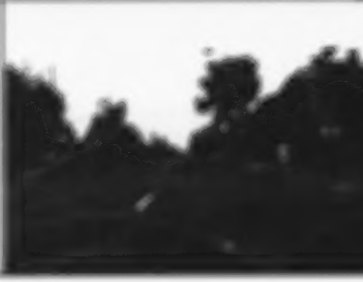
5) Thank Participant.

If participant appears distressed, then refer them to:

6) University of Calgary Counselling Services 220-5893

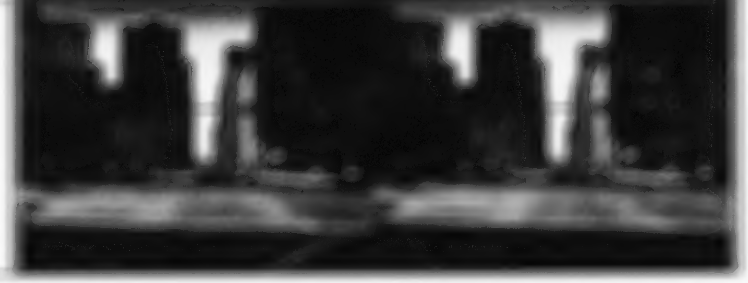
7) Dr. Jeff Caird (O) 220-5571

Appendix I: Modified Change Blindness Intersections

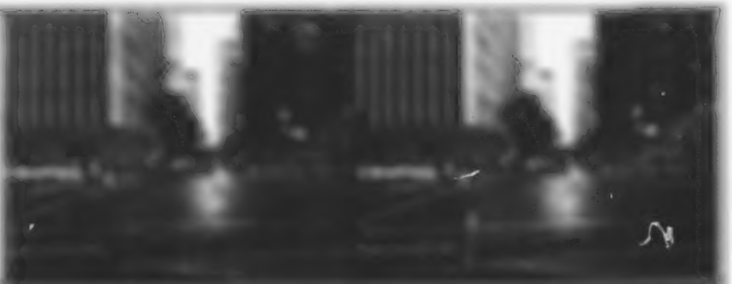
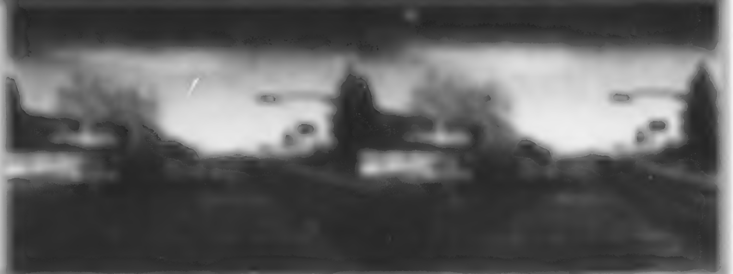
Order 1	Image	Direction	Go/No go	Change	Relevancy	Image A	Image A'
1	MontL23A	Left	No Go	Car	Relevant		
2	Monts11A	Straight	Go	None			
3	MontR6A	Right	No Go	Yellow light	Irrelevant		

	4CatL9A	Left	Go	Train	Irrelevant	
	5CatL1A	Left	Go	Pedestrian	Irrelevant	
	6CatR13A	Right	Go	Car	Irrelevant	

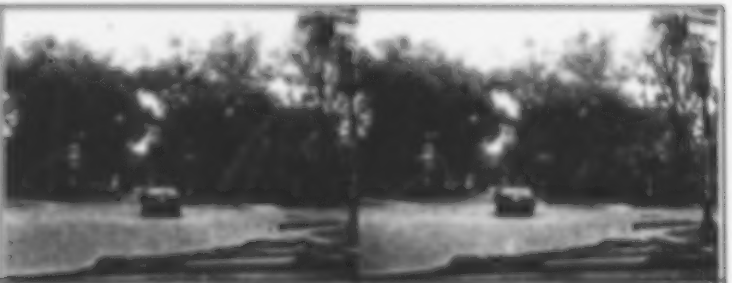
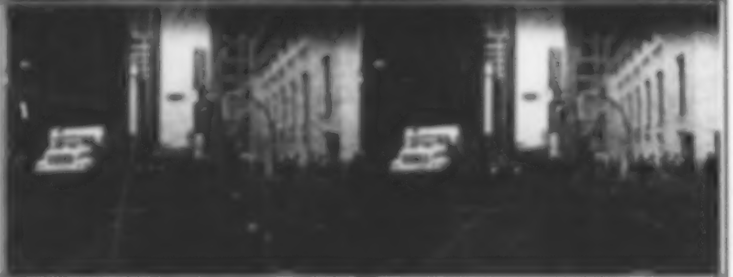
	[illegible]	Left	No Go	Car	Relevant	
	[illegible]	Straight	No Go	Pedestrian	Relevant	
	[illegible]	Straight	No Go	Pedestrian	Relevant	

	[illegible]	Left	No Go	None		
	[illegible]	Right	Go	None		
	[illegible]	Straight	No Go	Pedestrian	Relevant	

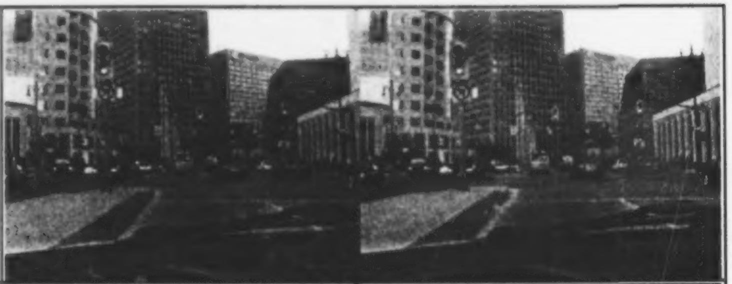
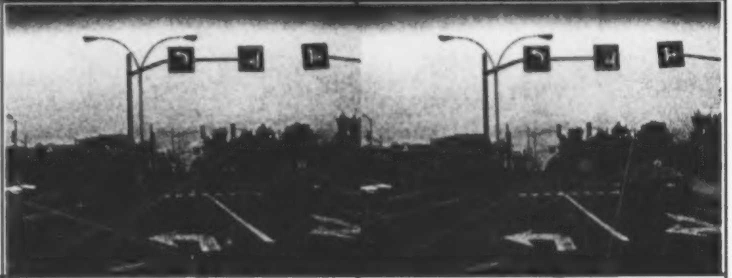
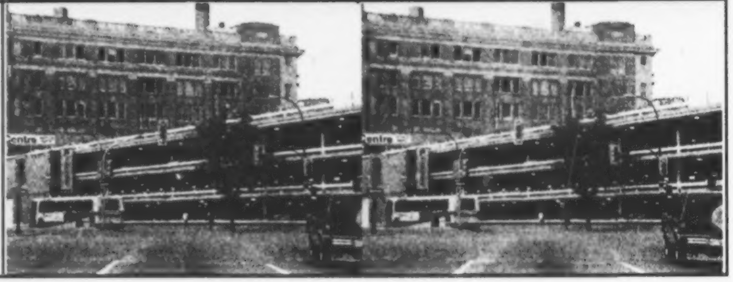
	[illegible]	Straight	Go	Yellow light	Relevant	
	[illegible]	Left	Go	None		
	[illegible]	Left	No Go	No turning sign	Relevant	

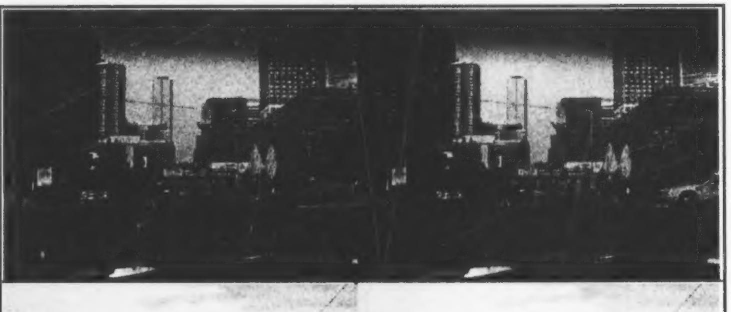
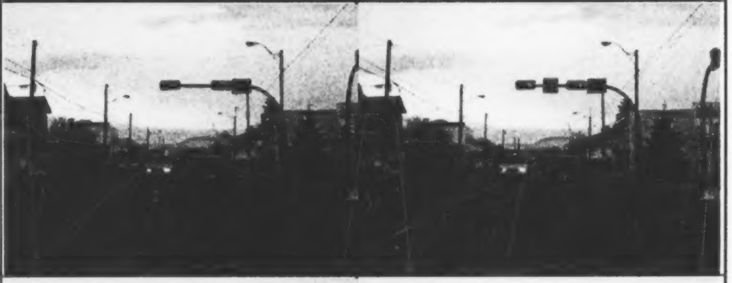
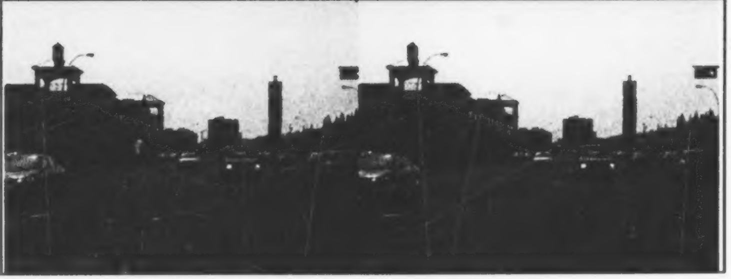
16Munis15A	Straight	Go	Jeep brake	Irrelevant	
17CalL24A	Left	No Go	Car	Irrelevant	
16Minne3A	Left	No Go	Car	Irrelevant	

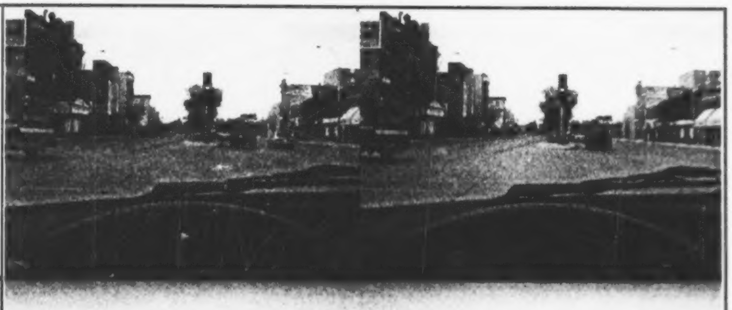
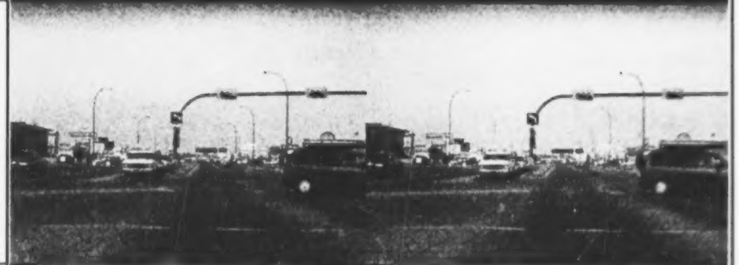
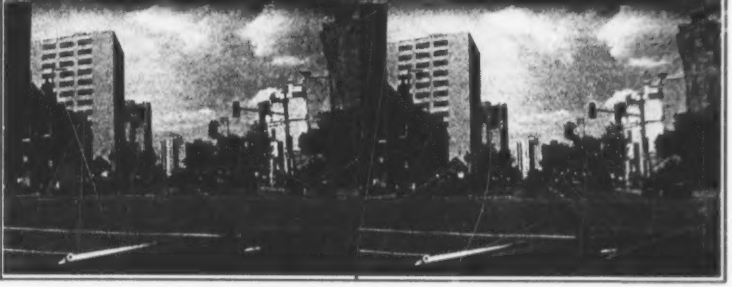
19	Monts21A	Straight	Go	None		
20	CalL20A	Left	No Go	Car	Relevant	
21	CalL8A	Left	No Go	No left sign	Relevant	

22	WinnR17A	Right	No Go	None		
23	Cals19A	Straight	No Go	Van	Relevant	
24	Winns4A	Straight	No Go	Pedestrian	Relevant	

25	WinnR9A	Right	No Go	None		
26	WinnL1A	Left	Go	Indicator lights	Irrelevant	
27	WinnR7A	Right	No Go	None		

28	Winns14A	Straight	Go	Light pole	Irrelevant	
29	MontL2A	Left	No Go	Pedestrian	Relevant	
30	WinnL23A	Left	Go	None		

31	Cals18A	Straight	No Go	Taxi	Relevant	
32	Cals7A	Straight	Go	1-way sign	Irrelevant	
33	CalL3A	Left	No Go	Yellow arrow	Relevant	

34	WinnL12A	Left	Go	Car	Irrelevant	
35	Cals13A	Straight	No Go	Pedestrian	Relevant	
36	Monts25A	Straight	Go	None		

Appendix J: Average Luminance for Objects that Change within Intersection Images

Order of Appearance	Name	Avg. Change Absent	Avg. Change Present	Luminance Change
1	MontL23A	16.3	37.39	-21.09
3	MontR6A	10.5	9.22	1.28
4	CalL9A	32.8	29.43	3.37
5	CalL1A	19.93	13.86	6.07
6	CalR15A	12.47	24.03	-22.56
7	WinnL11A	20.13	21.89	-1.76
8	Cals2A	36.22	28.15	8.07
9	Monts3A	6.56	12.03	-5.47
12	Cals21A	21.01	16.69	4.32
13	Cals23A	49.87	43.15	6.72
15	CalL5A	67.7	49.31	18.39
16	Monts15A	13.4	15.65	-2.16
17	CalL24A	25.39	22.92	2.47
18	Winns3A	25.95	50.02	-24.07
20	CalL20A	23.95	43.27	-19.32
21	CalL8A	64.88	26.92	37.96
23	Cals19A	13.12	11.94	1.18
24	Winns4A	9.34	7.71	1.63
26	WinnL1A	14.94	21.61	-6.67
28	Winns14A	17.51	22.98	-5.47
29	MontL2A	5.58	6.52	-0.94
31	Cals18A	9.04	33.16	-24.12
32	Cals7A	61.33	23.49	37.84
33	CalL3A	12.48	11.37	1.11
34	WinnL12A	25.75	20.02	5.73
35	Cals13A	35.27	22.45	12.82

Notes: The listing above is for order 1. Luminance was measured using a Minolta photometer (Model No. LS 100) at a distance of one metre from the screen. Intersections without changes are listed below.

Appearing	Name
2	Monts11A
10	MontL20A
11	WinnR22A
14	WinnL20A
19	Monts21A
22	WinnR17A
25	WinnR9A
27	WinnR7A
30	WinnL23A
36	Monts25A

Appendix K: Angular Subtense of Changed Objects in Intersection Images

(Order 1)

Int. #	**Intersection**	**Object Changing**	**Visual Angle (θ)[1] (in °)**
1	MontL23A	Car	1.35 x 0.94
3	MontR6A	Yellow light	0.19 x 0.19
4	CalL9A	C-train	0.91 x 0.68
5	CalL1A	Pedestrian	0.67 x 2.10
6	CalR15A	Car	1.55 x 1.77
7	WinnL11A	Car	1.16 x 0.79
8	Cals2A	Pedestrian	0.52 x 1.53
9	Monts3A	Pedestrian	1.16 x 2.24
12	Cals21A	Pedestrian	0.26 x 1.08
13	Cals23A	Yellow light	0.26 x 0.22
15	CalL5A	Left turn sign	0.71 x 0.71
16	Monts15A	Jeep brake lights	0.28 x 0.19
17	CalL24A	Car	0.84 x 0.68
18	Winns3A	Store front	0.98 x 0.72
20	CalL20A	Car	0.27 x 0.80
21	CalL8A	No left sign	1.06 x 1.06
23	Cals19A	Van	2.23 x 1.97
24	Winns4A	Pedestrian	0.34 x 1.90
26	WinnL1A	Car indicator lights	0.53 x 0.15
28	Winns14A	Light post	Signal: 0.47 x 0.82, Pole: 3.63 x 0.075
29	MontL2A	Pedestrian	0.49 x 1.59
31	Cals18A	Taxi	4.2 x 2.25
32	Cals7A	One-way sign	0.93 x 0.93
33	CalL3A	Yellow light	0.26 x 0.15
34	WinnL12A	Car	1.87 x 1.01
35	Cals13A	Pedestrian	0.49 x 1.50

[1] Visual angle (θ) represents the visual angle of the object on the retina of the driver seated 300 cm from the projection screen. Visual angles are in degrees and are width and height, respectively. Intersection images, 2, 10, 11, 14, 19, 22, 25, 27, 30, and 36 did not have changes.

(Order 2)

Int. #	Intersection	Object Changing	Visual Angle (θ)[1] (in°)
1	Winns5A	Store front	0.98 x 0.72
3	CalL20A	Car	0.27 x 0.80
4	CalL8A	No left sign	1.06 x 1.06
6	Cals19A	Van	2.23 x 1.97
7	Winns4A	Pedestrian	0.34 x 1.90
9	WinnL1A	Car indicator lights	0.53 x 0.15
11	Winns14A	Light post	Signal: 0.47 x 0.82, Pole: 3.63 x 0.075
12	MontL2A	Pedestrian	0.49 x 1.59
14	Cals18A	Taxi	4.2 x 2.25
15	Cals7A	One-way sign	0.93 x 0.93
16	CalL3A	Yellow light	0.26 x 0.15
17	WinnL12A	Car	1.87 x 1.01
18	Cals13A	Pedestrian	0.49 x 1.50
20	MontL23A	Car	1.35 x 0.94
22	MontR6A	Yellow light	0.19 x 0.19
23	CalL9A	C-train	0.91 x 0.68
24	CalL1A	Pedestrian	0.67 x 2.10
25	CalR15A	Car	1.55 x 1.77
26	WinnL11A	Car	1.16 x 0.79
27	Cals2A	Pedestrian	0.52 x 1.53
28	Monts3A	Pedestrian	1.16 x 2.24
31	Cals21A	Pedestrian	0.26 x 1.08
32	Cals23A	Yellow light	0.26 x 0.22
34	CalL5A	Left turn sign	0.71 x 0.71
35	Monts15A	Jeep brake lights	0.28 x 0.19
36	CalL24A	Car	0.84 x 0.68

[1] Visual angle (θ) represents the visual angle of the object on the retina of the driver seated 300 cm from the projection screen. Visual angles are in degrees and are width and height, respectively. Intersection images 2, 5, 8, 10, 13, 19, 21, 29, 30, and 33 did not have changes.

Appendix E: Intersection Turn Directions, Correct Action, Type of Change, and Presentation Time.

Order No.	Intersection	Direction	Correct Action	Change	Relevance	Time
1	[illegible]	Left		None		8
2	[illegible]	Right		None		8
3	[illegible]	Left		None		8
4	[illegible]	Right		None		8
5	[illegible]	Straight		None		8
6	[illegible]	Straight		None		8
7	[illegible]	Left	No go	Car	Relevant	8
8	[illegible]	Straight	Go	None		8
9	[illegible]	Right	No go	Yellow light	Irrelevant	2
10	[illegible]	Left	Go	Train	Irrelevant	8
11	[illegible]	Left	Go	Pedestrian	Relevant/Irrelevant	2
12	[illegible]	Right	Go	Car	Irrelevant	8
13	[illegible]	Left	No go	Car	Relevant	2
14	[illegible]	Straight	No go	Pedestrian	Relevant/Irrelevant	2
15	[illegible]	Straight	No go	Pedestrian	Relevant	8
16	[illegible]	Left	No go	None		8
17	[illegible]	Right	Go	None		8
18	[illegible]	Straight	No go	Pedestrian	Relevant	2
19	[illegible]	Straight	No go	Yellow light	Relevant	2
20	[illegible]	Left	Go	None		2
21	[illegible]	Left	No go	No turn sign	Relevant	8
22	[illegible]	Straight	Go	Dog Walker	Irrelevant	2
23	[illegible]	Left	No go	Car	Irrelevant	8
24	[illegible]	Straight	No go	Store front	Irrelevant	8
25	[illegible]	Straight	Go	None		2
26	[illegible]	Left	No go	Car	Relevant	8
27	[illegible]	Left	No go	No left sign	Relevant	2
28	[illegible]	Right	No go	None		8
29	[illegible]	Straight	Go	Van	Irrelevant	8
30	[illegible]	Straight	No go	Pedestrian	Relevant	2
31	[illegible]	Right	Go	None		2
32	[illegible]	Left	Go	Car indicator lights	Irrelevant	8
33	[illegible]	Right	No go	None		2
34	[illegible]	Straight	Go	Light pole	Irrelevant	8
35	[illegible]	Left	No go	Pedestrian	Relevant	8
36	[illegible]	Left	Go	None		2
37	[illegible]	Straight	No go	Taxi	Relevant	8
38	[illegible]	Straight	Go	One way sign	Irrelevant	8
39	[illegible]	Left	No go	Yellow light	Relevant	2
40	[illegible]	Left	Go	Car	Irrelevant	2
41	[illegible]	Straight	Go	Pedestrian	Relevant	8
42	[illegible]	Straight	Go	None		8

Order No	Intersection	Direction	Go/Stop	Change	Relevance	Time
1	[illegible]	Left		None		[illegible]
2	[illegible]	Right		None		[illegible]
3	[illegible]	Left		None		[illegible]
4	[illegible]	Right		None		[illegible]
5	[illegible]	Straight		None		[illegible]
6	[illegible]	Straight		None		[illegible]
7	[illegible]	Straight	Stop	[illegible]	Irrelevant	[illegible]
8	[illegible]	Straight	Go	None		[illegible]
9	[illegible]	Left	Stop	Car	Relevant	[illegible]
10	[illegible]	Left	Stop	[illegible]	Relevant	[illegible]
11	[illegible]	Right	Stop	None		[illegible]
12	[illegible]	Straight	Go	[illegible]	Irrelevant	[illegible]
13	[illegible]	Straight	Stop	Pedestrian	Relevant	[illegible]
14	[illegible]	Right	Go	None		[illegible]
15	[illegible]	Left	Go	[illegible]	Irrelevant	[illegible]
16	[illegible]	Right	Stop	None		[illegible]
17	[illegible]	Straight	Go	[illegible]	Irrelevant	[illegible]
18	[illegible]	Left	Stop	Pedestrian	Relevant	[illegible]
19	[illegible]	Left	Go	None		[illegible]
20	[illegible]	Straight	Stop	[illegible]	Relevant	[illegible]
21	[illegible]	Straight	Go	[illegible]	Irrelevant	[illegible]
22	[illegible]	Left	Stop	Yellow light	Relevant	[illegible]
23	[illegible]	Left	Go	Car	Irrelevant	[illegible]
24	[illegible]	Straight	Go	Pedestrian	Relevant	[illegible]
25	[illegible]	Straight	Go	None		[illegible]
26	[illegible]	Left	Stop	Car	Relevant	[illegible]
27	[illegible]	Straight	Go	None		[illegible]
28	[illegible]	Right	Stop	Yellow light	Irrelevant	[illegible]
29	[illegible]	Left	Go	[illegible]	Irrelevant	[illegible]
30	[illegible]	Left	Go	Pedestrian	Relevant/Irrelevant	[illegible]
31	[illegible]	Right	Go	Car	Irrelevant	[illegible]
32	[illegible]	Left	Stop	Car	Relevant	[illegible]
33	[illegible]	Straight	Stop	Pedestrian	Relevant/Irrelevant	[illegible]
34	[illegible]	Straight	Stop	Pedestrian	Relevant	[illegible]
35	[illegible]	Left	Stop	None		[illegible]
36	[illegible]	Right	Go	None		[illegible]
37	[illegible]	Straight	Stop	Pedestrian	Relevant	[illegible]
38	[illegible]	Straight	Stop	Yellow light	Relevant	[illegible]
39	[illegible]	Left	Go	None		[illegible]
40	[illegible]	Left	Stop	[illegible]	Relevant	[illegible]
41	[illegible]	Straight	Go	[illegible]	Irrelevant	[illegible]
42	[illegible]	Left	Stop	Car	Irrelevant	[illegible]

APPENDIX VI: Experimental Protocol – Driving Simulator Study

General Instructions

Welcome Participant – Introduce self

Provide participant with informed consent

Thank you very much for participating in this study. It should take about one hour to complete. I would like to remind you that you are free to withdraw from this study at any time. Please look through the informed consent. If you have any questions, please do not hesitate to ask.

Participant reads / signs form

Do you have any questions?

Now I will assess your visual acuity and contrast sensitivity. This is just to get an idea of your general visual status.

Test visual acuity. Record
Test contrast sensitivity. Record

If participant does not meet acuity or contrast sensitivity guidelines, ask participant to [illegible]

Simulator Start-up

a) Turn on host and channel computers
b) Turn projectors on
c) Calibrate steering wheel
d) Run HyperDrive software
e) Load appropriate Scenario (e.g., start with Training Run, then load the correct order for the participant)

START WITH EITHER SIMULATOR INSTRUCTIONS OR CHANGE BLINDNESS INSTRUCTIONS DEPENDING ON ORDER PARTICIPANT IS ASSIGNED TO

INTRODUCE SIMULATOR AND STUDY

Today you will be driving in a vehicle simulator. The simulator is designed to simulate real life driving in a controlled environment. During the study, you will drive through a number of situations just as you would when you drive in your vehicle. In particular, you will drive through a number of intersections.

GENERAL INSTRUCTIONS

- *Take each participant to the simulator (get in passenger side to explain things)*
- *Explain how to adjust seat, steering wheel and have them get in their comfort*
- *Show them the emergency stop button*
- *Ensure the [illegible] are illuminated so they are in a [illegible]*

While you are driving the simulator, you may stop at any time if you need to. You can either press the big red button on your right or come to a stop, put it into park, and exit the vehicle.
Please do not push the button unless you need to.

Once you are sitting comfortably, you will drive through a traffic environment to familiarize you with how the car handles and how the environment looks. If you would like to stop at any time, just let me know. Although I will be seated at the workstation behind you, I can hear you through a microphone (in the visor) and you can hear me on this speaker. Let's test it out so you understand how our communication will work.

1. Go to authoring station.
2. Test microphone and headset with participant.
3. Read the rest of the instructions over the headset.

Before you begin, I will just give you some instructions about how the car works. Please DO NOT start driving yet. Just like in a real car, you will put it into drive and press the accelerator to start moving when I tell you to begin the trial. During the practice session drive as you normally would and observe the rules of the road. Occasionally, the program will give you information on the screen about when to stop, when to turn and reminders about driving the speed limit. Please read these messages and do what they say.

After certain sections of the practice trial, the simulator will give you a message that says "Prepare to move to a new location". The simulator screens will go blank and when the road scene reappears, you may begin driving again. This will also occur at the end of each trial in the experimental section.

Finally, you should be aware that if you crash into other cars, pedestrians or objects on the road, a crash screen will appear (red screen) and you will hear a crash noise in the car. If this happens, the simulator will return you to the beginning of the section you are at and you can begin again.

PRACTICE TRIAL

The purpose the practice scenario is to familiarize you with how the simulator works and responds to your actions. During the practice section, you will encounter a variety of everyday driving situations such as straight driving, turns, and a variety of intersections. You should follow the rules of the road by following the speed limit and obeying signs and traffic lights.

1. *Start practice hyperdrive trial (TrainingRun2).*
2. *Type the participant's number into the data collection window.*

If you have any questions about what to do, please ask. *(Answer any questions).*
You may begin driving now.

- *Observe participant's physical reactions while driving. Look for signs of nausea and distress. If signs become visible, stop simulation immediately and have participant exit the vehicle and sit down. Further monitor the participant for 10 minutes.*

- *Once the participant has completed the practice section, instruct them to wait while the experimental scenarios are loaded. Load appropriate experimental scenario.*

Do you have any questions about how the simulator works or what is expected of you?
We will now begin the experimental section of the study.

EXPERIMENTAL TRIALS

You will now drive through the primary roadways of the study and will interact with several intersections. Just as you did in the practice section, you will follow all the rules of the road as you would in your own vehicle. Remember that you will be moved to a new trial at the end of each trial. You may begin each trial as soon as the road scene reappears. Please follow any instructions that are presented on the screen or through the microphone.

Do you have any questions about what is expected of you?

- *Observe participant's physical reactions while driving. Look for signs of nausea and distress. If signs become visible, stop simulation immediately and have participant exit the vehicle and sit down. Further monitor the participant for another 10 minutes.*

MOVE TO CHANGE BLINDNESS SECTION OR TO QUESTIONNAIRE SECTION AND END OF STUDY

CHANGE BLINDNESS INSTRUCTIONS

Now we will show you a series of intersections on a screen and ask you questions about them.

We will conduct three practice trials to get you familiar with this portion of the study. The practice session will consist of three intersections, each with the same questions.

On the screen in front, you will see either a left, right or straight ahead arrow. These arrows tell you the direction in which you wish to travel at the intersection that will be presented. When you have memorized the direction in which you will be travelling, tell me and I will start the trial. When the intersection appears, it will flash on and off for either 5 or 8 seconds. You should form a decision whether to go or not go in the direction that was indicated by the arrow, just as you would when you drive your own vehicle. When the intersection stops flashing, a screen will prompt you to make your decision to go or not go.

Once you have made your decision to go or not go, four questions will be presented about each intersection. The questions will be the same for all intersections.

Let's look at the practice trials.

Take participant through left, right and straight practice trials. Make sure to clarify any concerns and answer any questions. Leave interpretation of the intersection up to the participant.

EXPERIMENTAL TRIALS

The experimental section consists of 12 intersections that will be presented just as the practice trials were, with the same questions. For each intersection, you should form your decision to go or not go while the intersection is flashing. We will then go through the questions for each intersection just as we did in the practice session.

If you have any questions during the session or forget in which direction you were supposed to go, please let me know.

Do you have any questions?

Run through the 12 experimental trials.

MOVE TO SIMULATOR STUDY **OR** QUESTIONNAIRE SECTION AND END OF STUDY

PARTICIPANT QUESTIONNAIRES

Once the participant has left the Saturn or completed the change blindness study, seat them and have them fill out the BACKGROUND QUESTIONNAIRE (DEQ) and the DRIVER BEHAVIOUR QUESTIONNAIRE. This should take at least 20 minutes.

1) *Hand out DEQ. Allow participant to complete form. (Clarify questions if needed.)*

2) *Hand out Driver Behaviour Questionnaire. Allow participant to complete form.*
(Clarify questions if needed.)

3) *Give participant debriefing form. Go through the form with participant.*

4) *Ask questions about what they thought about the study.*
Write responses on qualitative form.

5) *Log Bonus Credit for Participation Pool / Pay older drivers for participation*

6) *Thank Participant.*

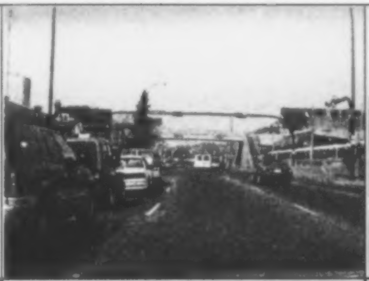
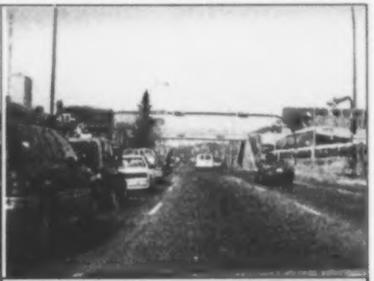
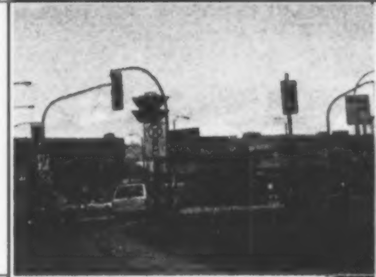
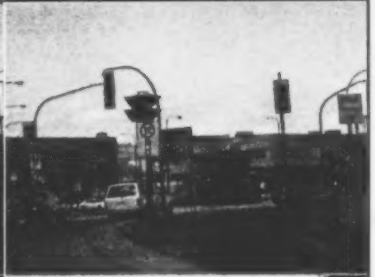
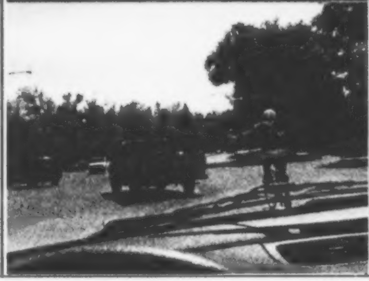
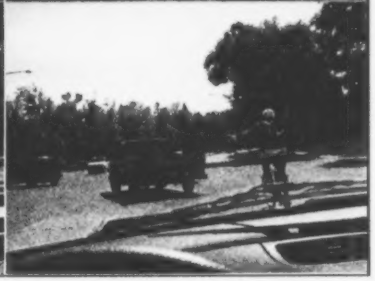
If participant appears distressed, then refer them to:

1) *University of Calgary Counseling Services 220-5893*

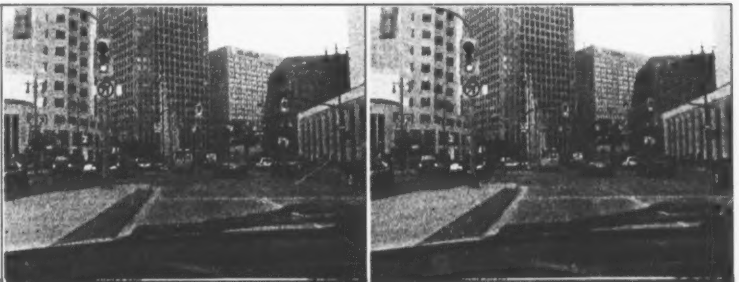
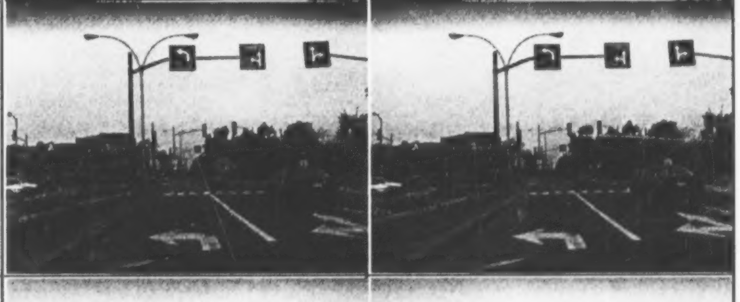
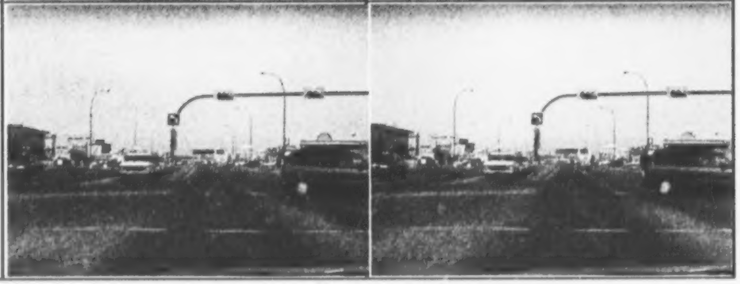
2) *Dr. Jeff Caird (O) 220-5571*

Appendix N: Simulation Flicker Images

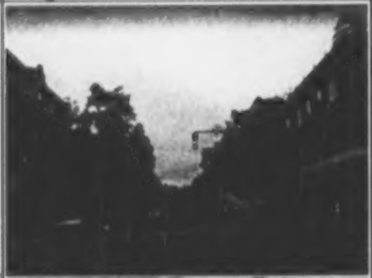
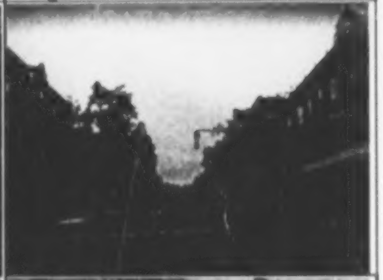
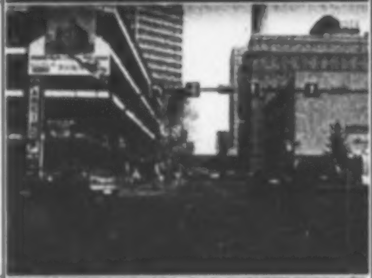
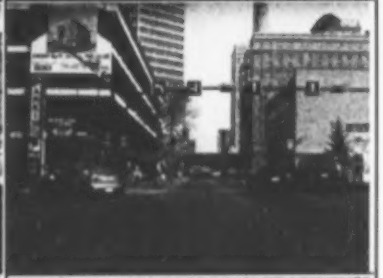
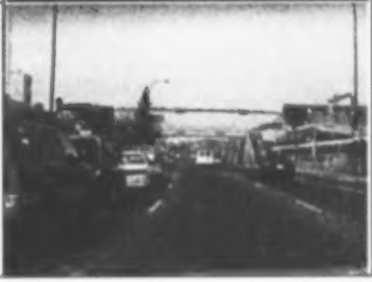
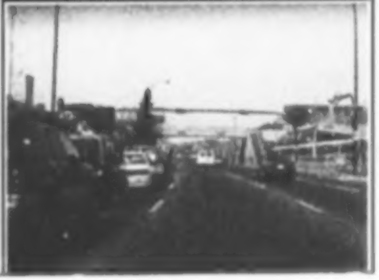
Order 1	Image	Direction	Go/No go	Change	Relevancy	Image A	Image A'
1	MontR6A	Right	No Go	Yellow light	Irrelevant		
2	CalL1A	Left	Go	Pedestrian	Irrelevant		
3	WinnL11A	Left	No Go	Car	Relevant		

4	Cals2A	Straight	No Go	Pedestrian	Relevant		
5	WinnR22A	Right	Go	None			
6	WinnL20A	Left	Go	None			

7	Monts15A	Straight	Go	Jeep brake	Irrelevant		
8	Monts21A	Straight	Go	None			
9	WinnR7A	Right	No Go	None			

10	Winns14A	Straight	Go	Light pole	Irrelevant	
11	MontL2A	Left	No Go	Pedestrian	Relevant	
12	Cals13A	Straight	No Go	Pedestrian	Relevant	

Appendix O: Significant Intersections Images

Order 1	Image	Direction	Go/No go	Change	Significant Effects	Image A	Image A'
2	Monts11A	Straight	Go	None	Age		
5	CalL1A	Left	Go	Pedestrian	Age		
8	Cals2A	Straight	No Go	Pedestrian	Age and Time		

9	Monts3A	Straight	No Go	Pedestrian	Age	
12	Cals21A	Straight	No Go	Pedestrian	Age and Time	
13	Cals23A	Straight	Go	Yellow light	Time	

15	CatL5A	Left	No Go	No turns sign	Age	
21	CatL8A	Left	No Go	No left sign	Age	
23	Cats19A	Straight	No Go	Van	Age	

26	WinnS6A	Straight	No Go	Pedestrian	Age	
27	WinnR7A	Right	No Go	None	Age and Time	
28	MontL2A	Left	No Go	Pedestrian	Age	

31	[illegible]	Straight	No Go	Taxi	Age	
32	[illegible]	Straight	No Go	Pedestrian	Relevant	